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(NASA-TM-X-71521) SECOND HEATED JETTISON TEST ON THE CENTAUR STANDARD SHROUD (NASA) 110 p HC $8.50 CSCL 22B

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SECOND HEATED JETTISON TEST ON THE CENTAUR STANDARD SHROUD

Lewis Research Center
Cleveland, Ohio

February 1974

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SECOND HEATED JETTISON TEST ON THE CENTAUR STANDARD SHROUD

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio

ABSTRACT

The second in a planned series of heated jettison tests on the Centaur Standard Shroud was conducted at NASA Plum Brook Station's Space Power Facility on January 16, 1974. The first 250-second portion of the test sequence involved heating the shroud with a specially-built fixture designed to provide a simulation of the heating environment encountered by the shroud during its ascent through the earth's atmosphere. The two heater halves, which were mounted on a rail system, were then retracted. This was followed by the jettison of the two shroud halves into catch nets positioned at 90° to the heater rails. The condition which made this test unique compared to the others in the test series was the alignment of the maximum thermal line with the shroud separation plane. Information on the test hardware, configuration, and sequence is presented. Shroud thermal and deflection data encountered during the heating portion of the test sequence is compared with free-skin design temperatures in various graphical formats.

INTRODUCTION

The Centaur Standard Shroud protects the payload of the Titan-Centaur launch vehicle during the ascent phase of the flight. To conserve weight, it is jettisoned as early in the flight as possible, while it is still hot from aerodynamic heating. Analysis of the possible flight trajectories and the shroud structure indicated that severe internal stresses could be built up prior to jettison. Calculations of the edge motion of the shroud during jettison indicated that the design clearance between the shroud and the payload could disappear, in the worst case.

An experimental program was conducted in the Space Power Facility at the NASA Lewis Research Center to verify the computer model of the shroud jettison event. The shroud was heated to simulate the expected 280-second flight trajectory then it was jettisoned.

A seven-megawatt, radiant heater was assembled in the vacuum chamber of the Space Power Facility. The heater was programmed to produce the desired temperature distribution with the plane of symmetry aligned with the separation plane of the shroud. Following the 250-second heating cycle the heater was pulled away to allow the shroud to be jettisoned. A special catch net system was built which allowed one half of the shroud to fall completely free of the launch vehicle while the second half rotated approximately 16° before being caught. The test was performed in a 20-torr environment.

Deflections of the shroud were measured during the heating cycle with straingages and deflectometers. Thermocouples measured the applied thermal condition. High-speed motion picture cameras were used to record the motions of the shroud during jettison.

It is the objective of this report to present a brief description of the test hardware, the operation sequence and the results of a preliminary data analysis.

APPARATUS

The overall arrangement of the test hardware in the Space Power Facility is shown in figure 1. The seven-megawatt heater was built in two halves that rolled on rails perpendicular to the facility rail system. The Centaur shroud was mounted on a Titan-Centaur interstage adapter. Its location in the 100-foot diameter chamber was chosen to allow one half of the shroud to fall completely free of the hinges before being caught in the net. The other half (the one with the dome) was caught after only 16° of rotation. The Centaur tanks were not used in this test because of the unnecessary complexity they would have added. In their place, a special structure was mounted on the

interstage adapter that allowed access to the inside of the shroud and supported the flight truss adapter, equipment module and a simulated pay-load. A photograph of the internal structure is shown in figure 2.

Catch Nets. Special catch-nets were constructed using a high temperature synthetic webbing supported by 6-inch-diameter aluminum pipe frames. The photograph in figure 3 shows the full-jettison catch net in position. The full jettison net frame was supported by cables attached to 10 disk brakes (five on each side) which served to absorb the energy imparted to that shroud half. The catch system was pre-tested using a model of a shroud half to insure that it would function properly without damage to the shroud.

Heater. The heater was designed to duplicate, in time and temperature, the condition expected in the ascent phase of the flight. The heater contained 5910 tungsten filament lamps inside a highly polished aluminum reflector. A detailed thermal analysis (the approach used is described in ref. 1) and extensive small scale tests were performed to verify the design concepts. The heater was divided into 18 separate control zones, 11 in the cylindrical section and 7 in the biconic section, to provide the proper circumferential temperature profiles. In addition the spacing of the lamps was varied within each zone to control the vertical distribution of heat. Because the desired temperature profiles were symmetrical around the maximum heat line, the 18 control zones were further divided into mirror-image half-zones (one on each side of the plane of symmetry). The arrangement of the control and mirror image half-zones is shown in figure 4. The maximum heat line for this test was at an azimuth of 0° (0° from the shroud separation plane).

Control Systems. Each control half-zone and its mirror image was powered by a separate SCR controller. The 18 controllers were programmed individually to reproduce the expected temperature vs time curve for their respective control zones. Abort limits were established to insure that the test would not proceed if any control half-zone or mirror image half-zone deviated more than a prescribed amount from its desired temperature curve.

A PDP-8 mini computer was used to conduct the test because of critical timing of events necessary. The sequence of events for this test is presented in Table 1.

INSTRUMENTATION

Thermocouples, straingages, deflectometers, and high-speed motion picture cameras were used to measure the performance of the shroud during the test. Digital data were recorded every second during the test, using an XDS 930 computer. FM analog recordings were also obtained of selected parameters. The coordinate system used to define the location of sensors on the shroud is shown in figure 5 and 6. The cylindrical section of the Centaur shroud is a complex structure composed of a corrugated outer skin bonded to a smooth inner skin supported by circumferential "Z" rings. A sketch of the structure and a typical free skin thermocuple installation is shown in figure 7. Free skin thermocouples were located as far from structural masses as possible to provide the best possible measurement of the thermal environment. Free skin ther-

mocouples at station 2626 in the cylindrical part of the shroud, and at station 2724 in the conic part were used to provide temperature feed back to the power controllers.

RESULTS

The heated jettison test was conducted on January 16, 1974, at an ambient pressure of 20 torr. The heater was programmed to produce the desired temperature distribution with the plane of symmetry displaced 0° from the shroud separation plane (see figure 4). The light half of the shroud (the one without the dome) was fully jettisoned and fell free of the hinges into the horizontal net. The other half was caught after only 16° of rotation.

Time histories of the control thermocouple readings are presented in figure 8 for the 18 control half-zones and the 18 mirror image half-zones. Included also on this figure are the desired temperature histories. Comparison of desired and measured temperatures shows that excellent agreement was obtained. The greatest deviation was in zone 10 where a 10° F deviation was observed in the mirror image half-zone. The instantaneous power applied to the shroud varies according to the slope of the desired temperature curve. The measured power applied to zone 1 is presented as an illustration in figure 9. The initial peaking power occured because the shroud was cooler than the set point when the heating cycle started. The power increased gradually, following the desired temperature curve. Very little power was needed near the end of the cycle because the required temperature was actually decreasing slowly.

Circumferential temperature profiles are presented in figure 10 at several stations and for several times during the heating cycle. Also shown are the desired temperature profiles. Comparison of the two indicates that very good agreement was obtained everywhere except at the top of the biconic section and at station 2250. The thermocouples at station 2250 are very close to the aft seal bulkhead which probably accounts for their low readings. This is supported by the fact that a thermocouple at station 2469, where the shroud skin thickness and the lamp spacing were the same as at station 2250, agreed very well with the desired curve. These deviations were observed early during the heater checkout tests and were deemed acceptable.

The shroud deflected during the heating cycle because of temperature gradients of as much as 90° F in the "Z" rings. The deflection was measured with potentiometer type deflectometers. Circumferential plots of their readings at several stations and at several times during the test are presented in figure 11. For reference purposes the desired temperature curves are also included in figure 11. Examination of these data indicated that the shroud assumed a pinched cross section with the narrow part at the shroud separation plane. The tendency for the shroud to pinch this way is resisted by the joint between the two halves. Consequently, when the shroud is separated the first motion is expected to be inward. Edge motions of the shroud were recorded by high speed motion picture cameras. At the time of this writing, the cameras data had not been fully analyzed and could not be included. How-

ever, it was observed that the first motion of the shroud edges was inward (about $3\frac{1}{2}$ inches) toward the payload. In addition to the cameras some short wooden sticks mounted in foam blocks were installed to indicated invasion of the payload envelope by the shroud. First inspection indicated that the payload envelope was not invaded.

Examination of the camera data also revealed small objects (tape-like in appearance) being blown off at high velocity from the Super*Zip near the hinge in Quadrant II (at approximately 100° azimuth).

CONCLUSIONS

A successful heated jettison test of the Centaur Shroud was performed in the Space Power Facility on January 16, 1974. The shroud was heated to the desired thermal condition with the axis of symmetry displaced 0° from the separation plane. Initial observations indicated that the shroud's first motion was inward but that it did not invade the payload envelope.

REFERENCE

1. Hemminger, Joseph A.: Computer Simulation of Temperatures on the Centaur Standard Shroud During Heated Jettison Tests. Paper presented at the Seventh Space Simulation Conference, Los Angles, Calif., Nov. 12-14, 1973.

Table 1.
SEQUENCE OF EVENTS

Event	Test Time
Start all recorders.	-10
Verify recorder start.	- 8
Start heating cycle.	0
Verify heaters started.	50 to 80
Color movie lights on.	160
Color cameras on.	165
Safe zone heaters.	250
Start heater retract.	250
Turn on movie lights.	272
Check heater clear.	272
Start cameras.	272 to 275
Arm seal pyro.	275
Fire seal pyro.	276
Verify seal pyro fired.	277
Arm instrument disconnects.	277
Fire instrument disconnects.	278
Verify instrument disconnects fired.	280
Arm Super*Zip for shroud jettison.	280
Fire Super*Zip.	281
Safe all systems.	295
Stop all recorders.	300

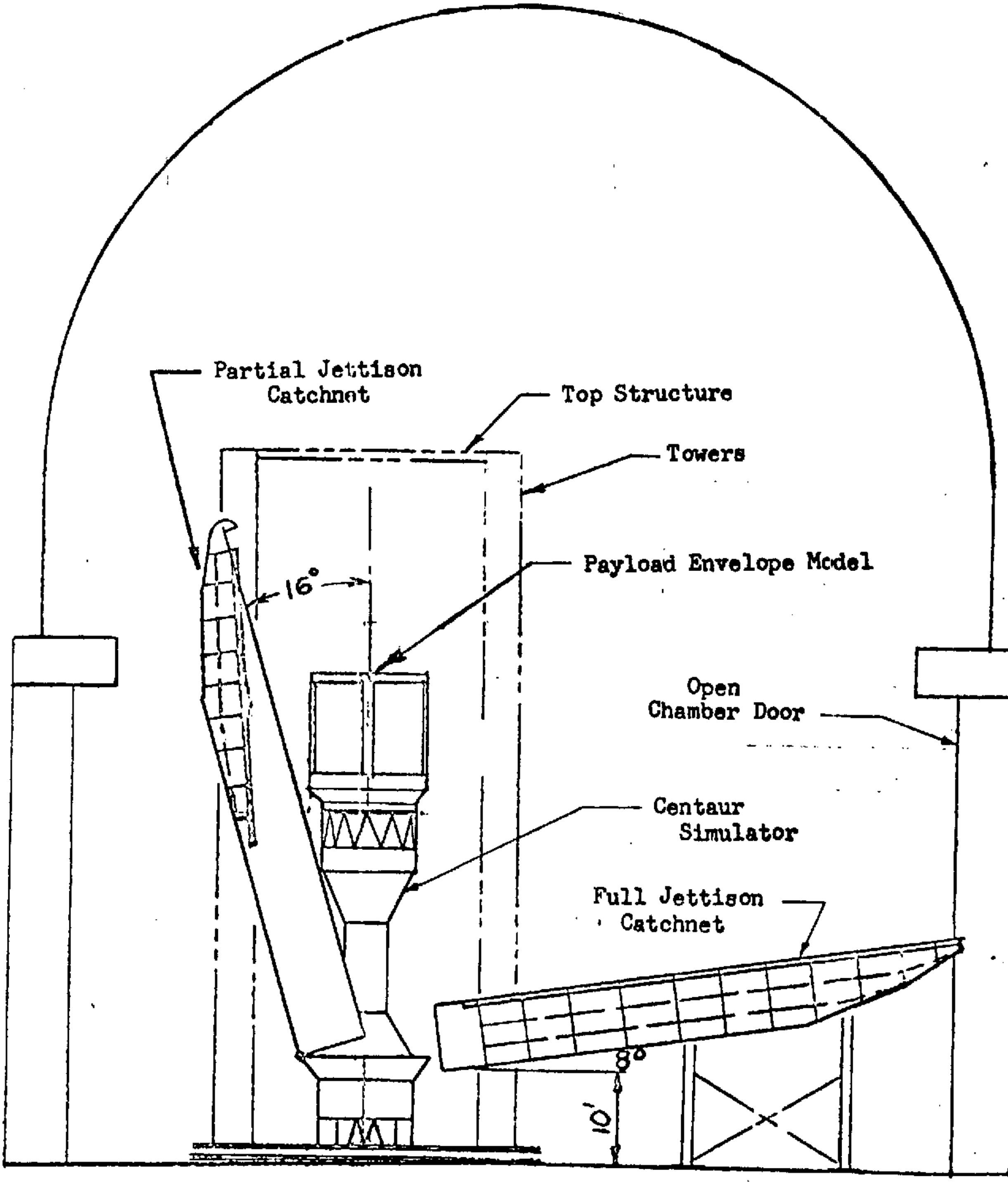


Figure 1. CSS in jettisoned position (view looking north).

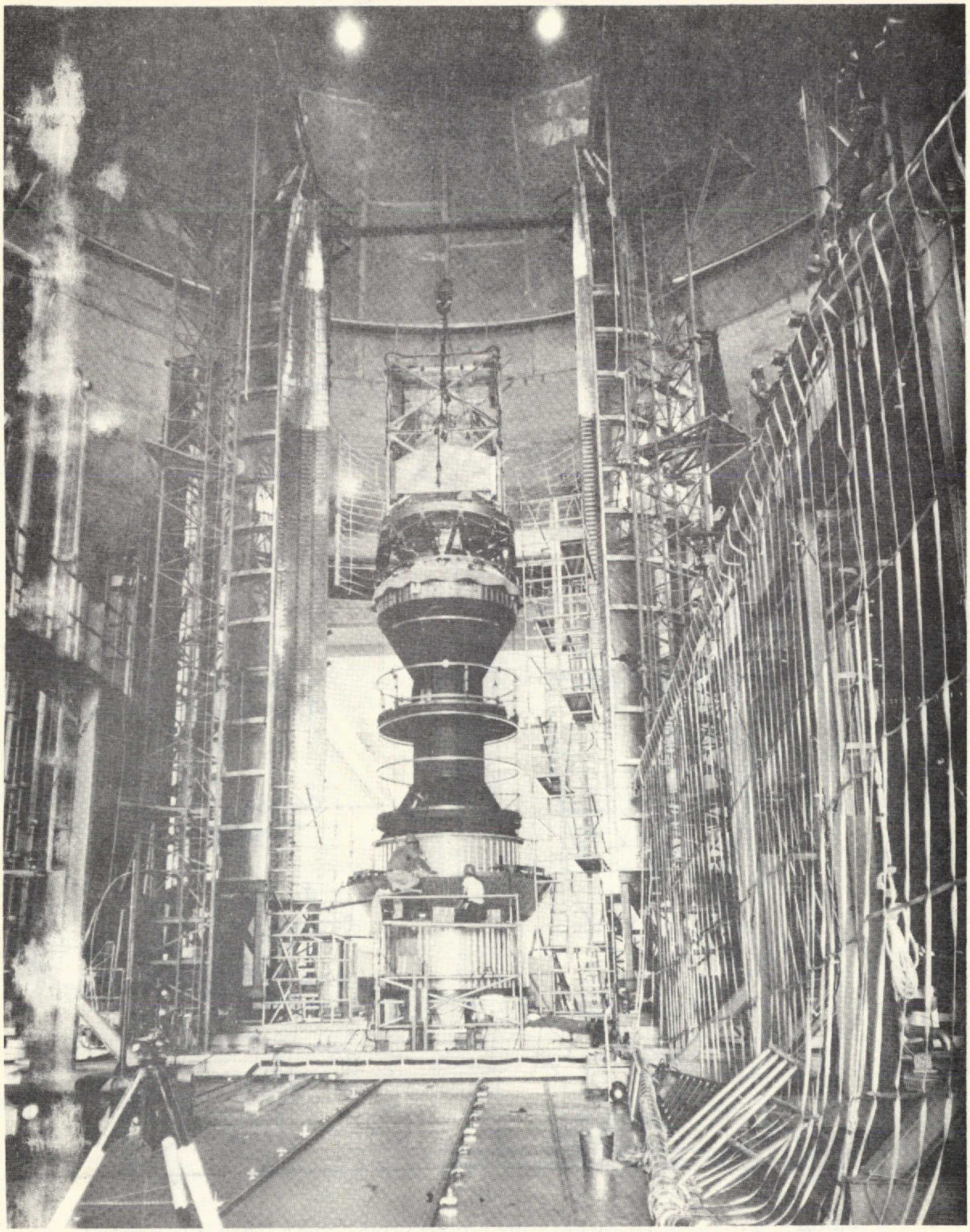


Figure 2. Photograph of internal structure.

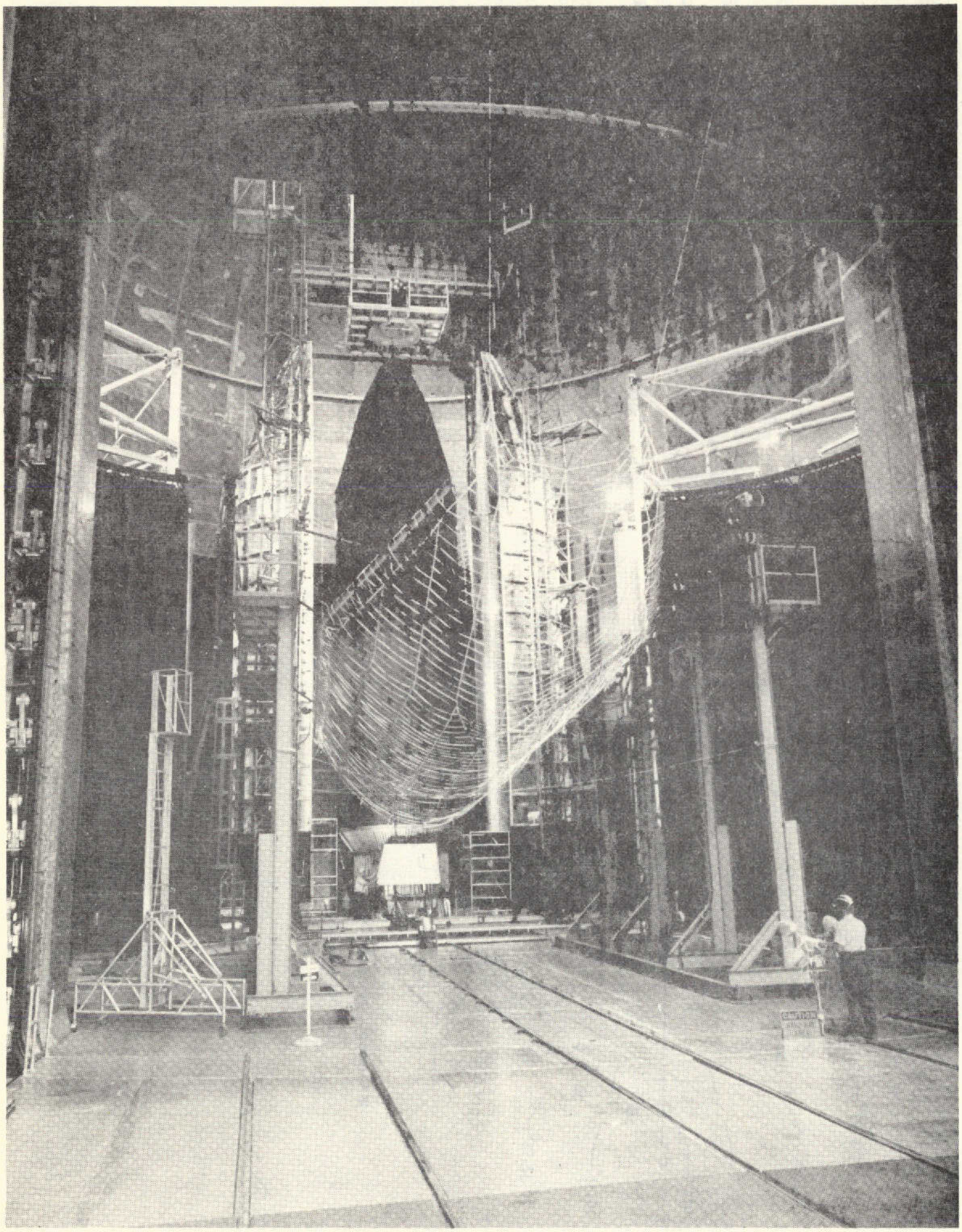
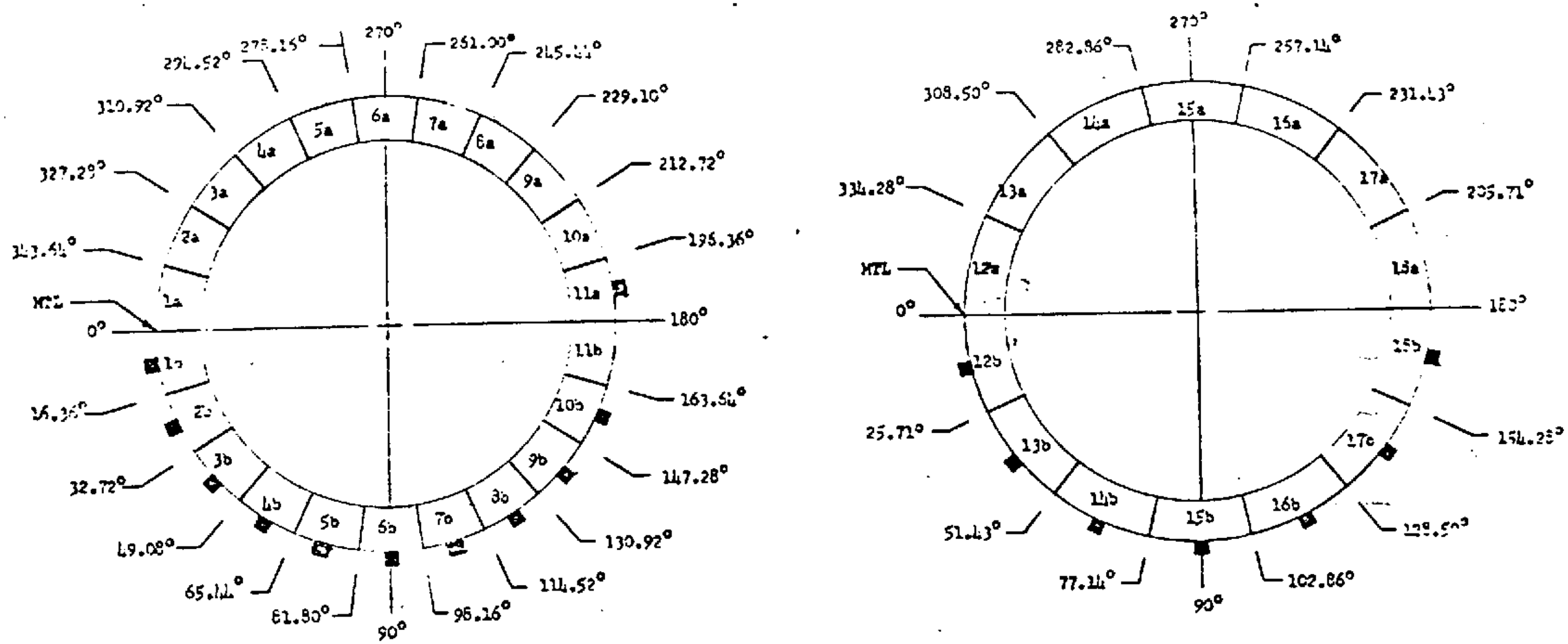


Figure 3. Photograph of test installation.



■ Control Thermocouple

(a) Station 2626.5, looking aft.

■ Control Thermocouples

(b) Station 2723.45 (15° cone), looking aft

Figure 4. Heater control zones and control thermocouple locations.

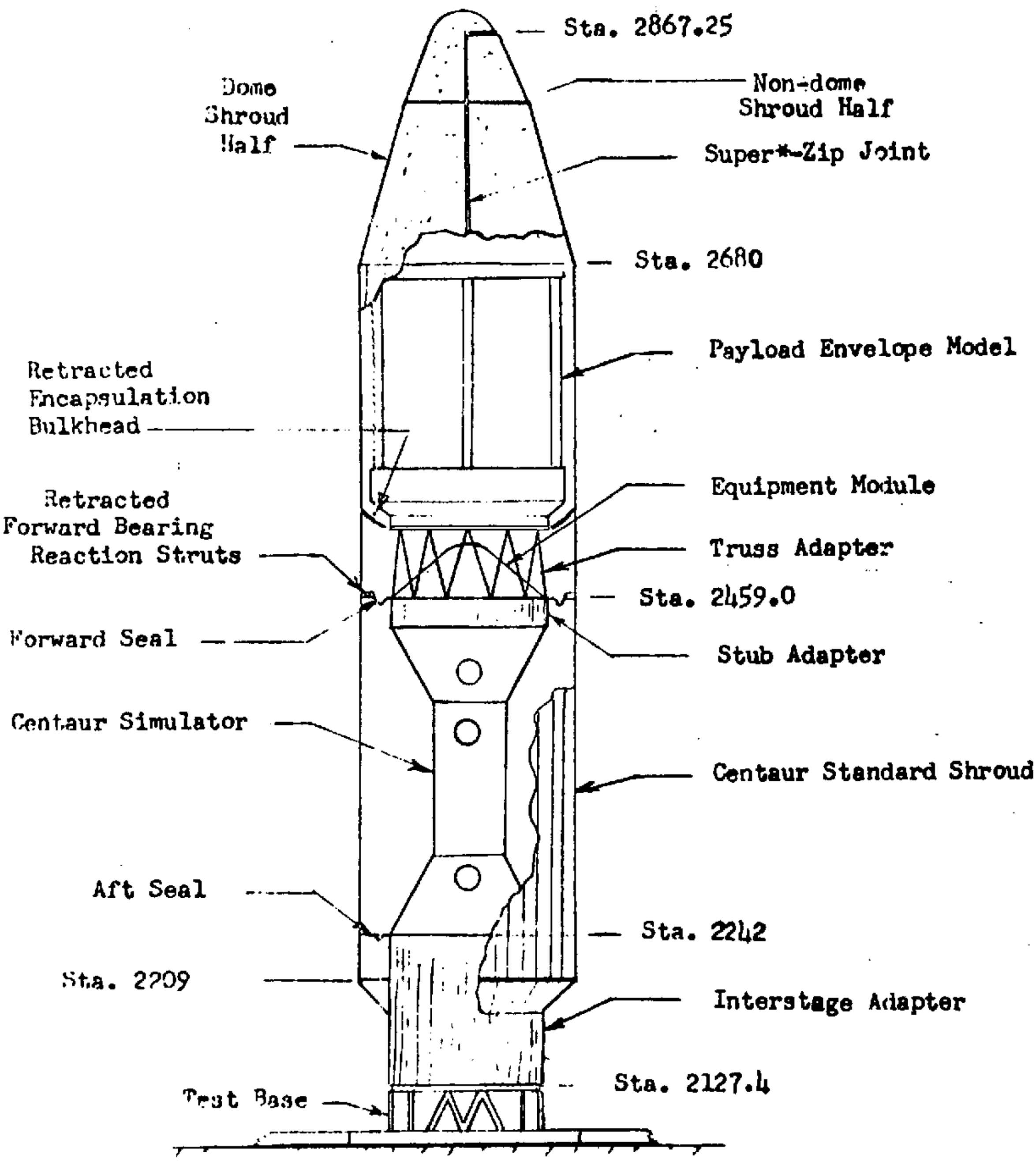


Figure 5. Axial coordinate notation - station locations (inches from datum).

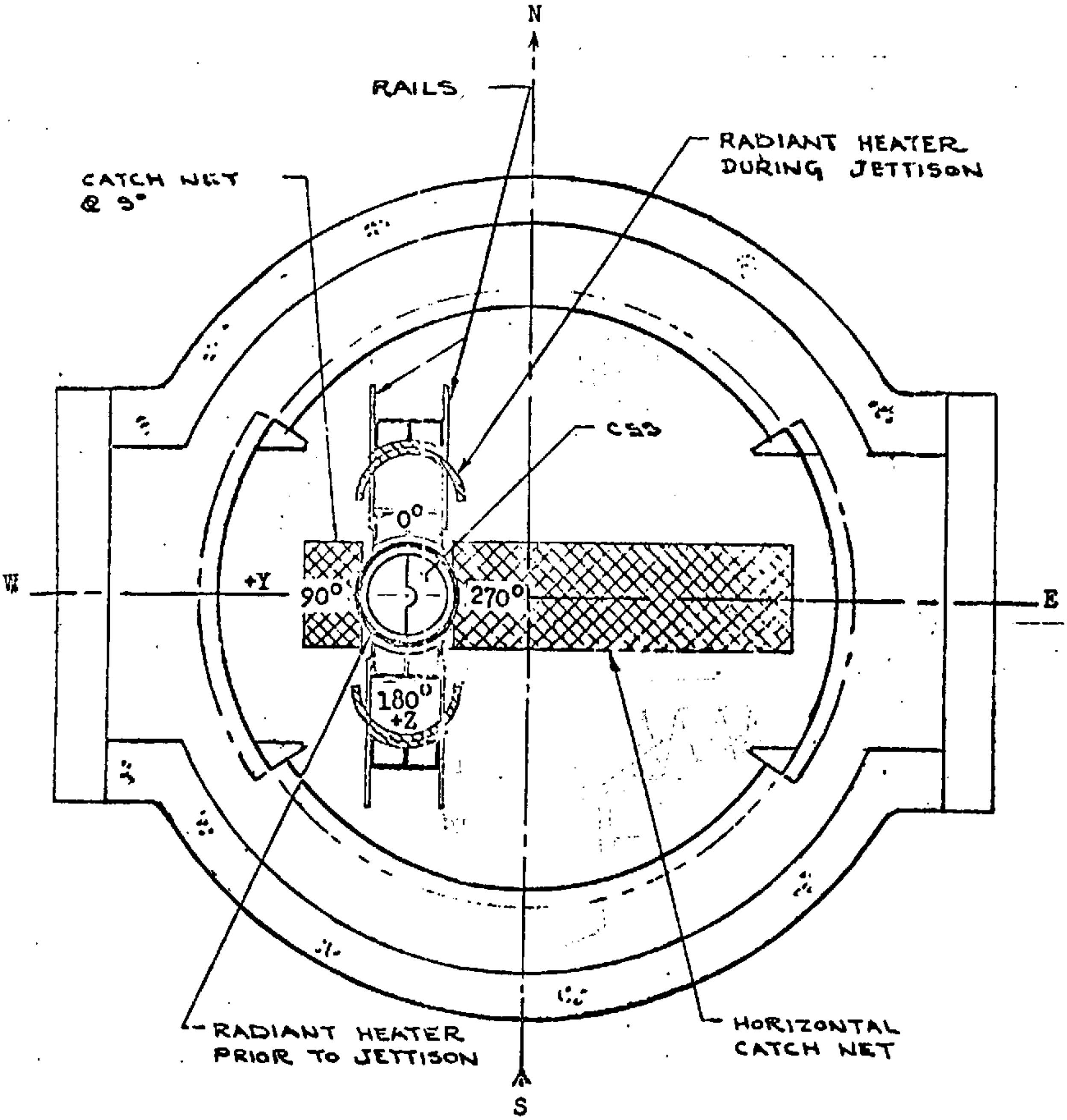
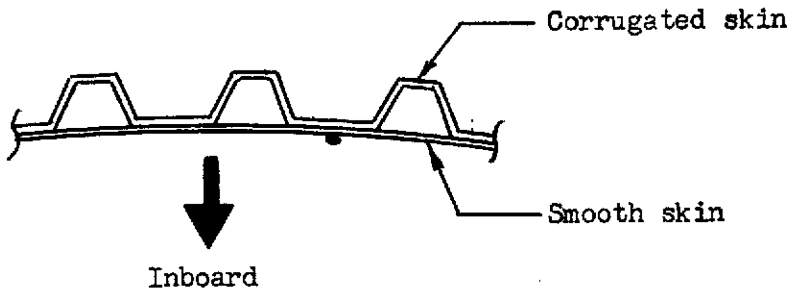
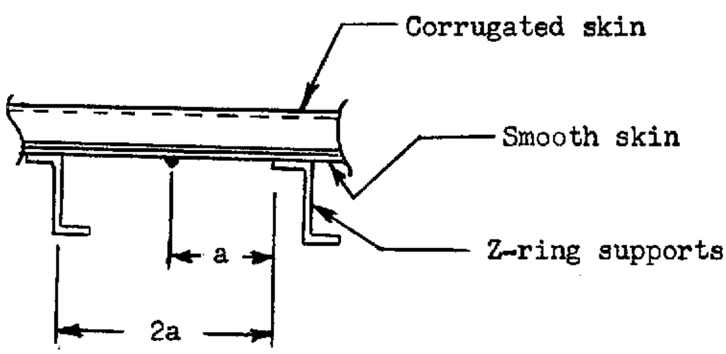


Figure 6. Angular coordinate notation - azimuth (plan view, looking down).



Note: thermocouple junctions located between "weldbonded" panels spot welds.



Typical mounting on cylindrical section

Figure 7. Free-skin thermocouple locations.

Figures 8.1 thru 8.36.

Design temperature and thermocouple histories
at heating zone control locations on CSS.

Figure 8.1

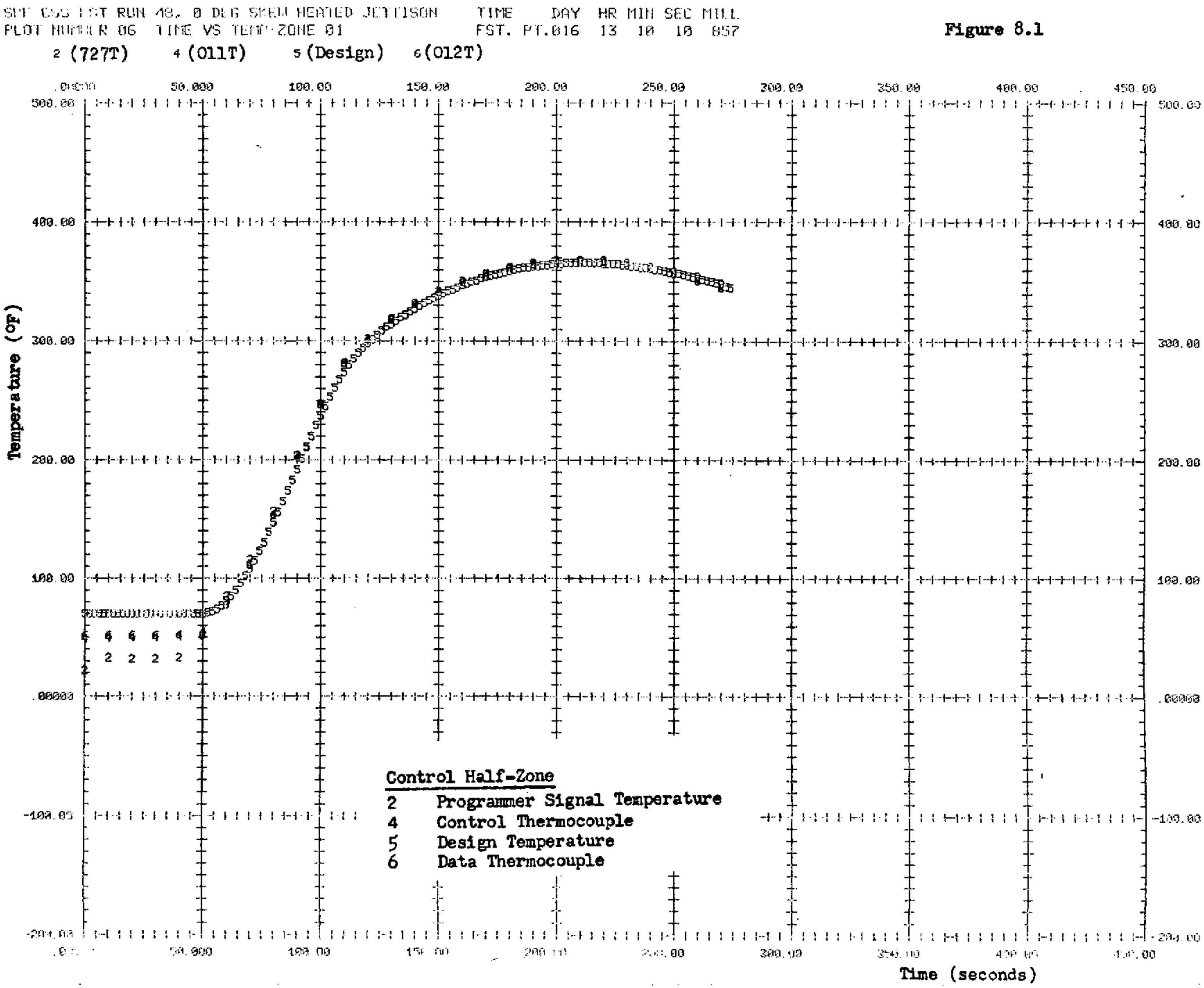
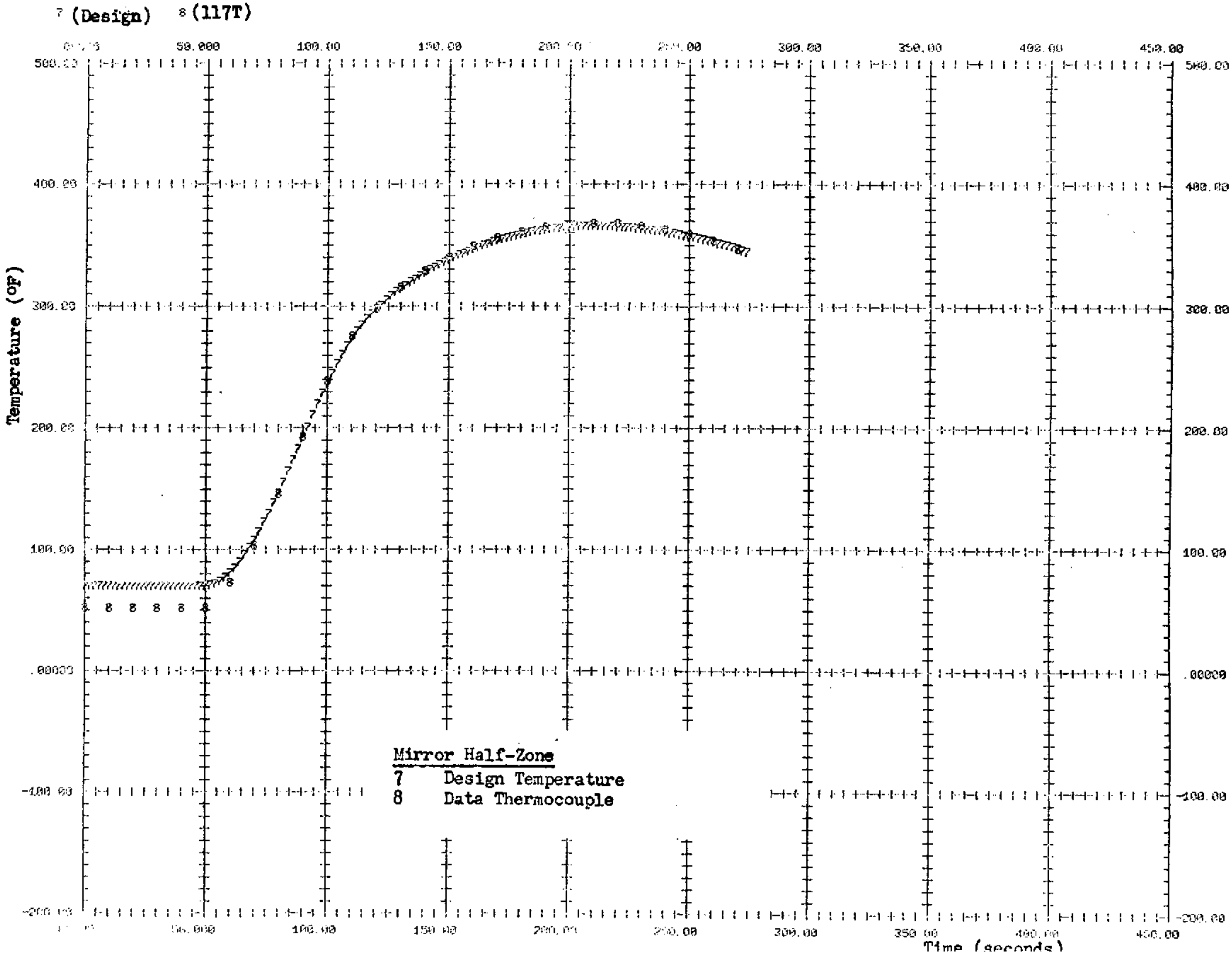
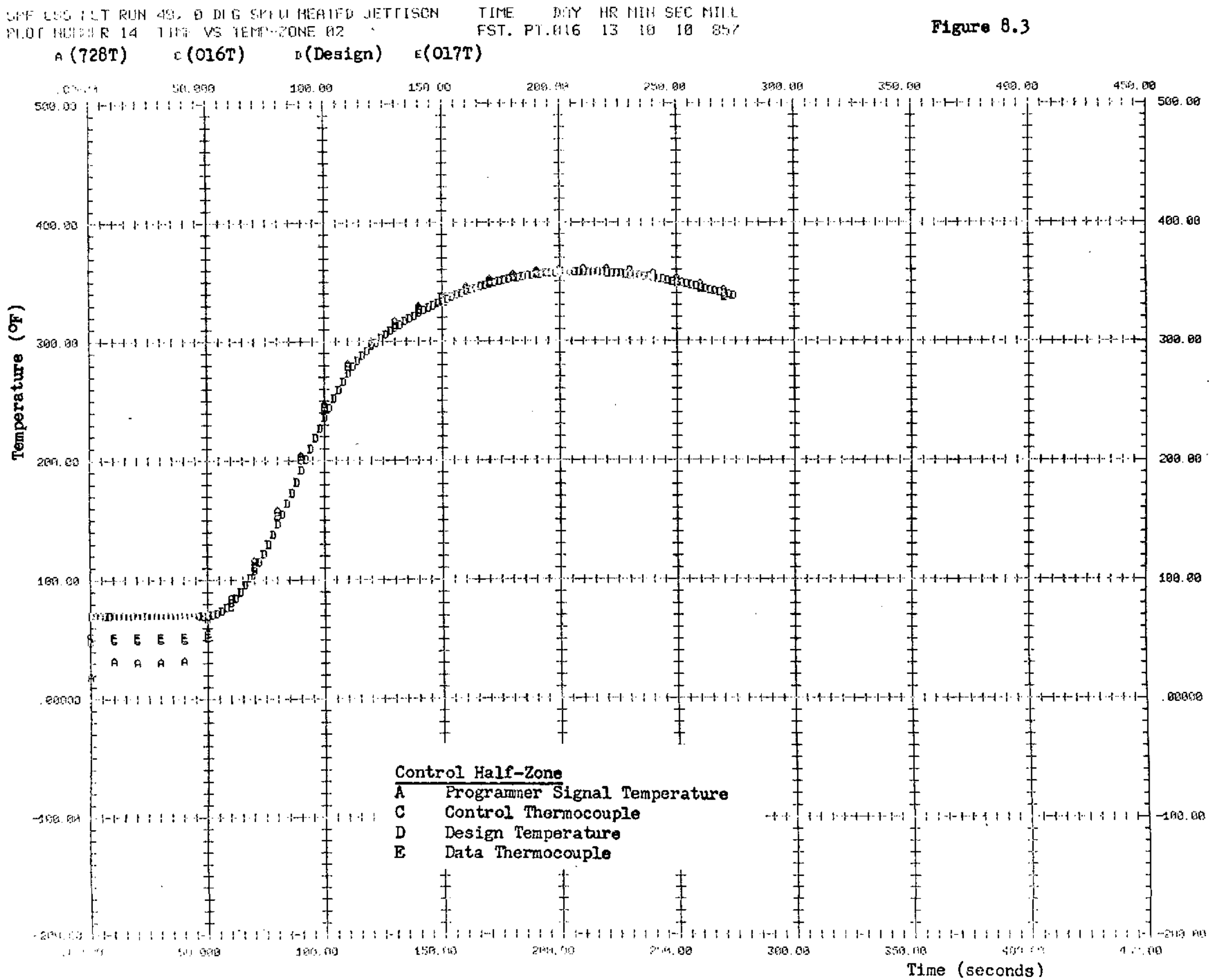

TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
2 (727T) 4 (011T) 5 (Design) 6 (012T)
Temperature (°F)
Time (seconds)
Control Half-Zone
2 Programmer Signal Temperature
4 Control Thermocouple
5 Design Temperature
6 Data Thermocouple

Figure 8.2

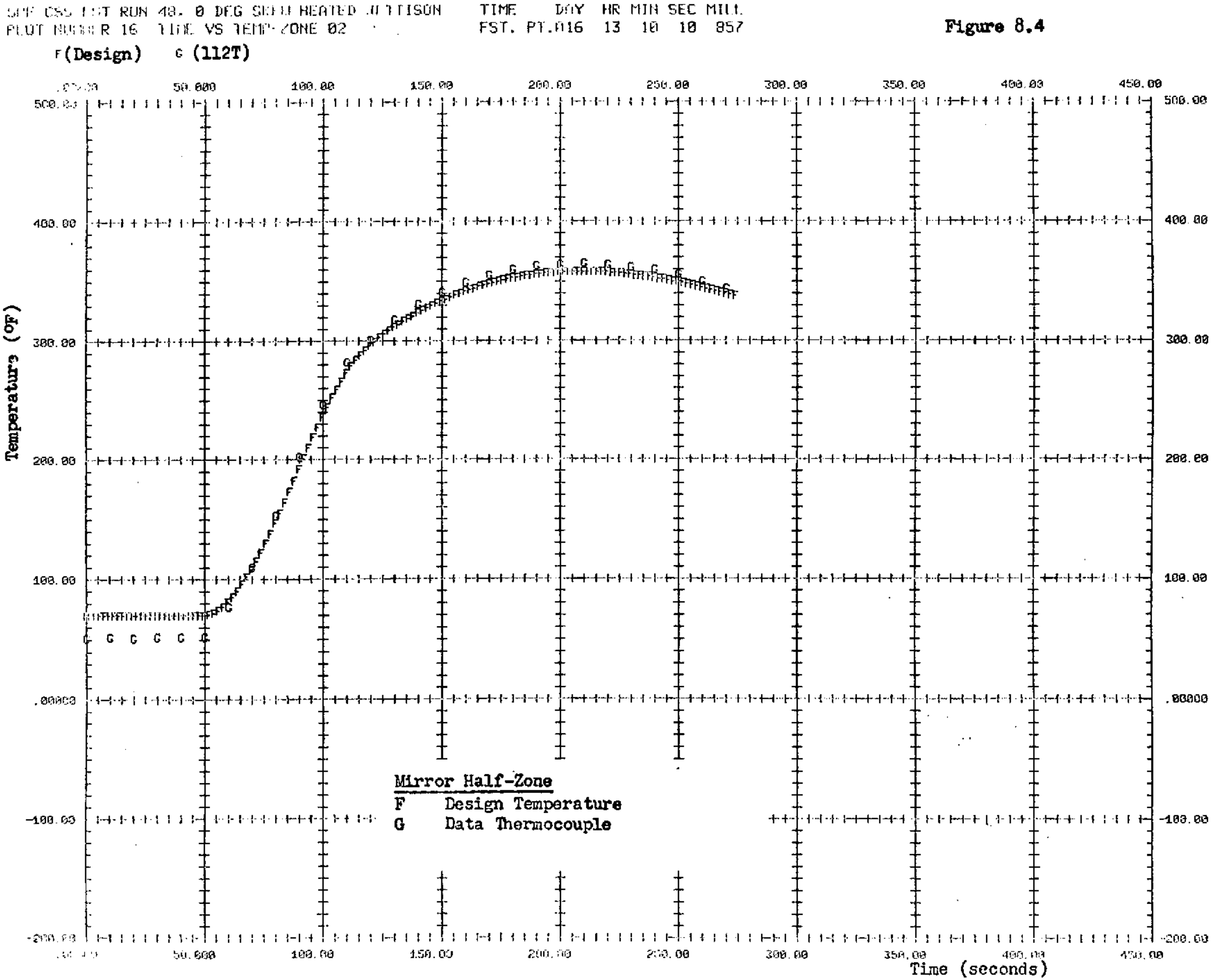

7 (Design)
8 (117T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
7 Design Temperature
8 Data Thermocouple



PLOT NUMBER 14 TIME VS TEMP-ZONE 02
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
A (728T) C (016T) D (Design) E (017T)
Temperature (°F)
Time (seconds)
Control Half-Zone
A Programmer Signal Temperature
C Control Thermocouple
D Design Temperature
E Data Thermocouple

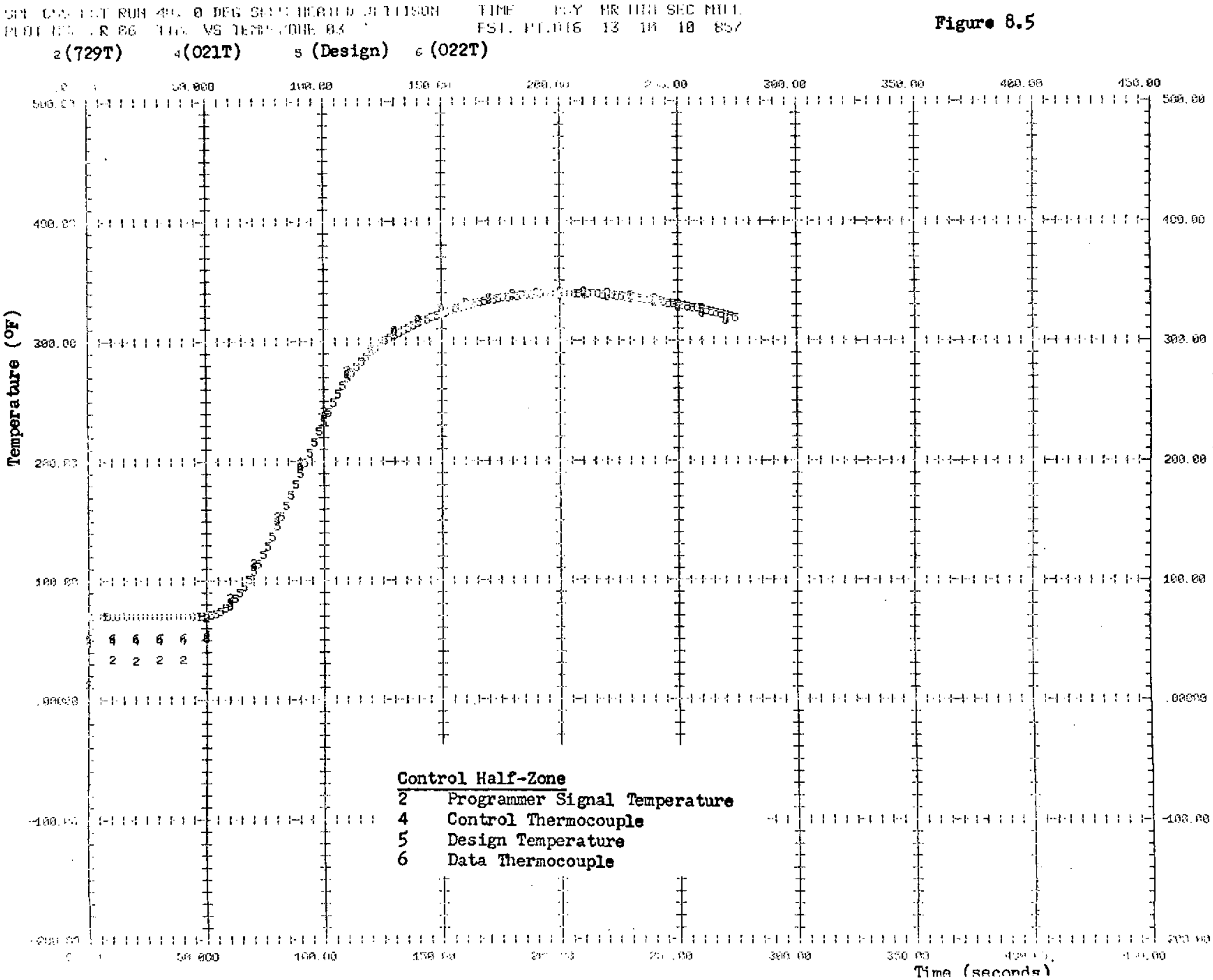
Figure 8.3

Figure 8.4



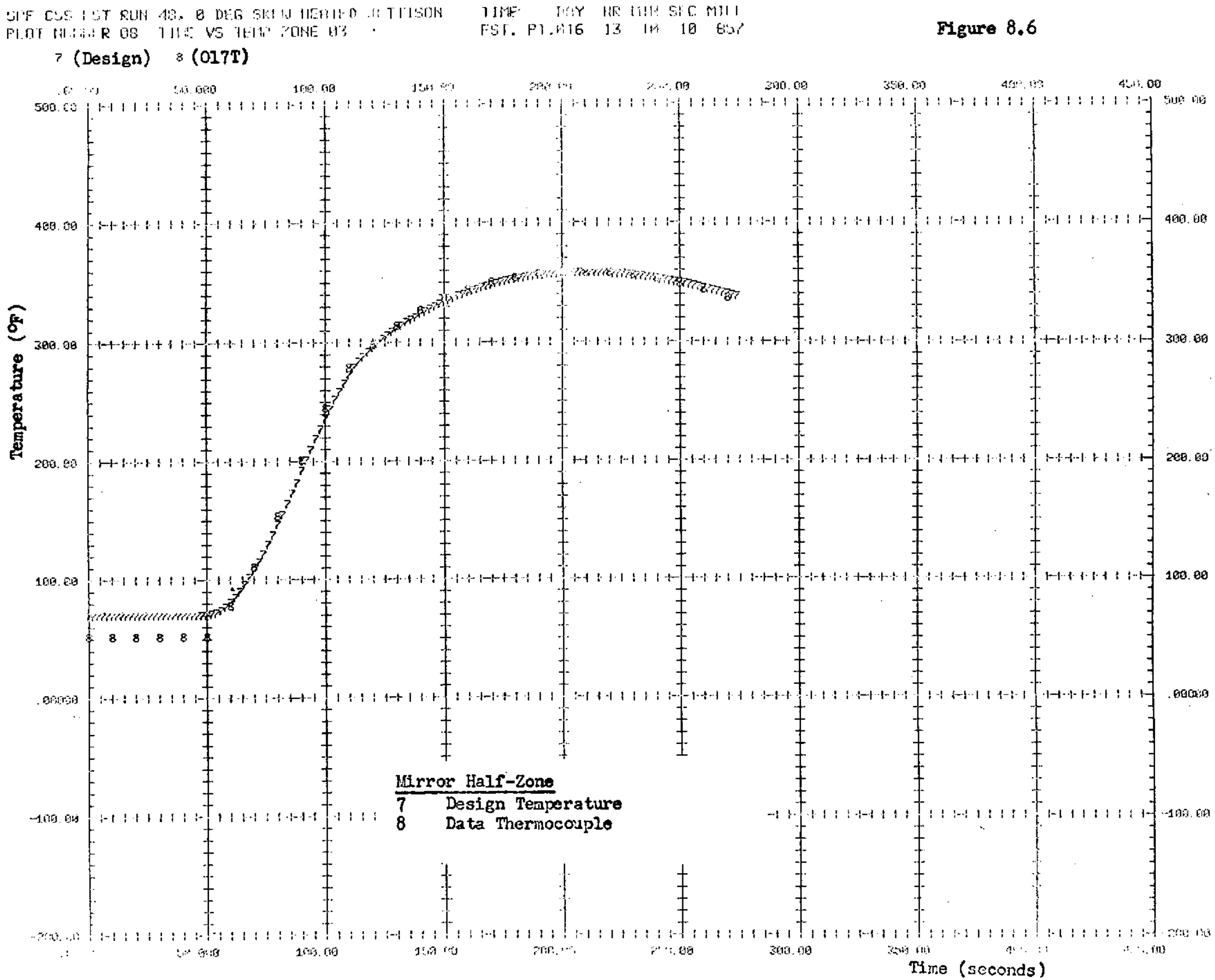
SPF CSS TST RUN 48. 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 16 TIME VS TEMP-ZONE 02
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
F(Design) G (112T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
F Design Temperature
G Data Thermocouple

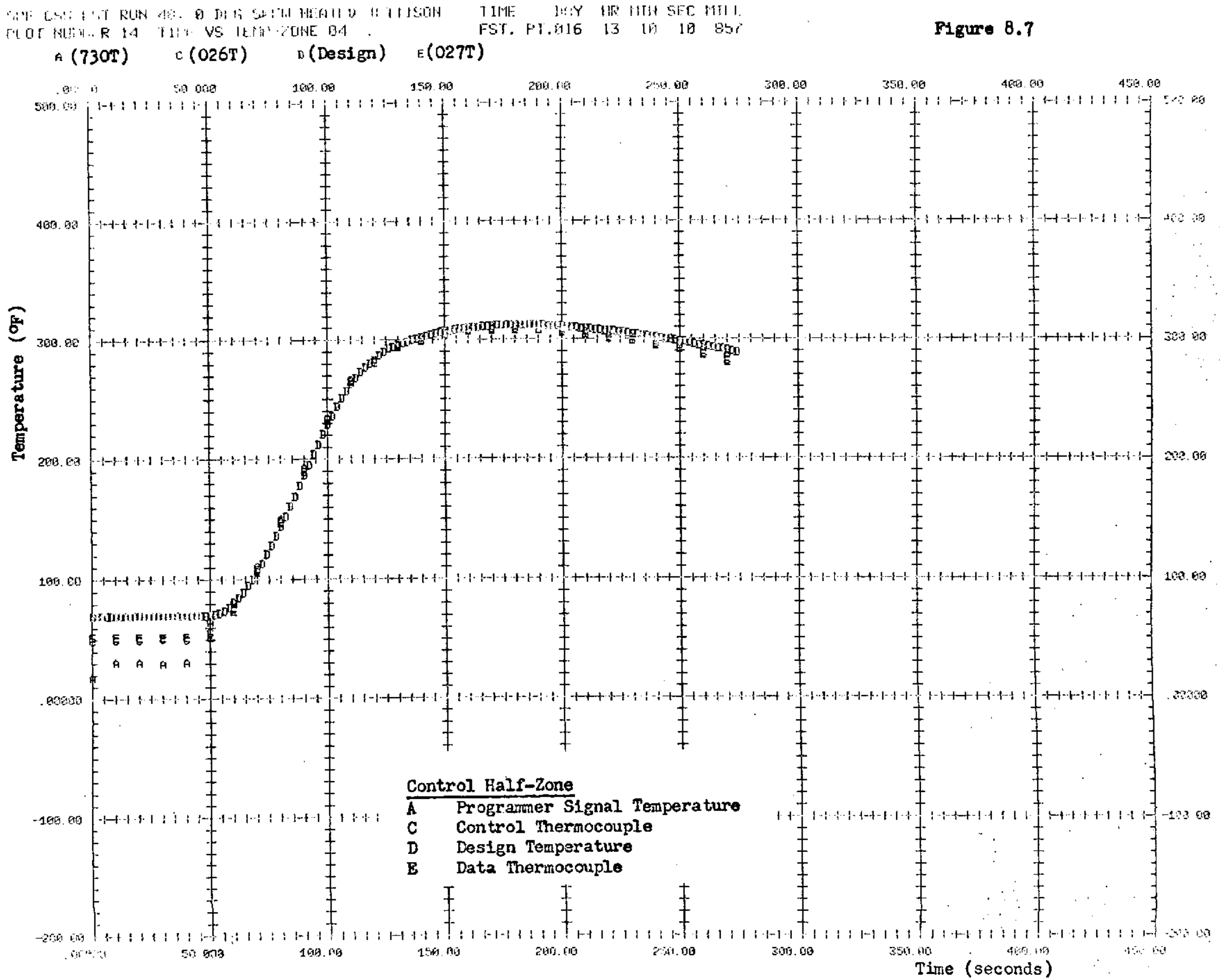
Figure 8.5



2 (729T)
4 (021T)
5 (Design)
6 (022T)
Temperature (°F)
Time (seconds)
Control Half-Zone
2 Programmer Signal Temperature
4 Control Thermocouple
5 Design Temperature
6 Data Thermocouple

Figure 8.6

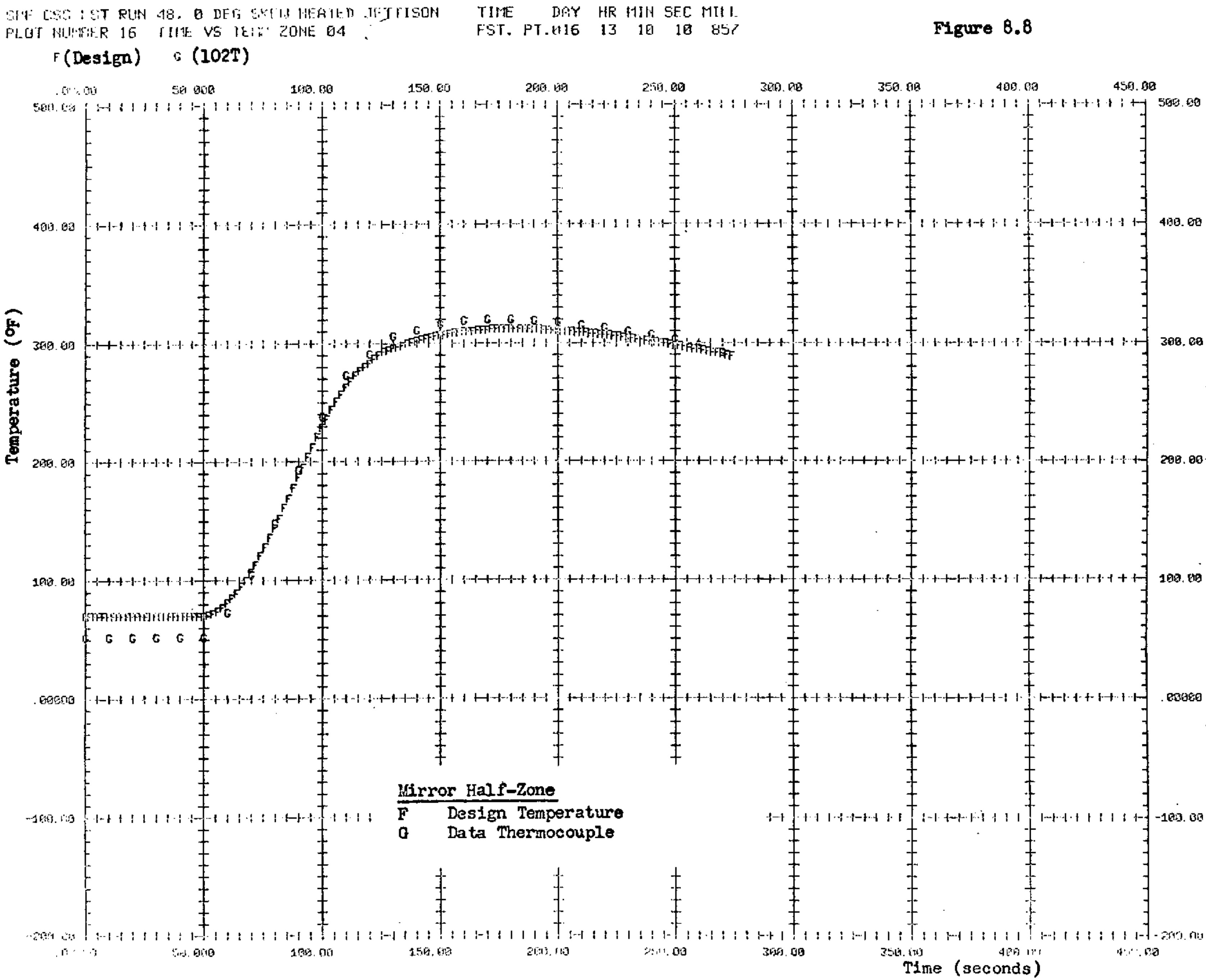

7 (Design) 8 (017T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
7 Design Temperature
8 Data Thermocouple



FST. PT.016 13 10 10 857
A (730T)
C (026T)
D (Design)
E (027T)
Temperature (°F)
Time (seconds)
Control Half-Zone
A Programmer Signal Temperature
C Control Thermocouple
D Design Temperature
E Data Thermocouple

Figure 8.7

Figure 8.8



SRF DSC TST RUN 48. 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 16 TIME VS TEMP ZONE 04
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
F(Design) G (102T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
F Design Temperature
G Data Thermocouple

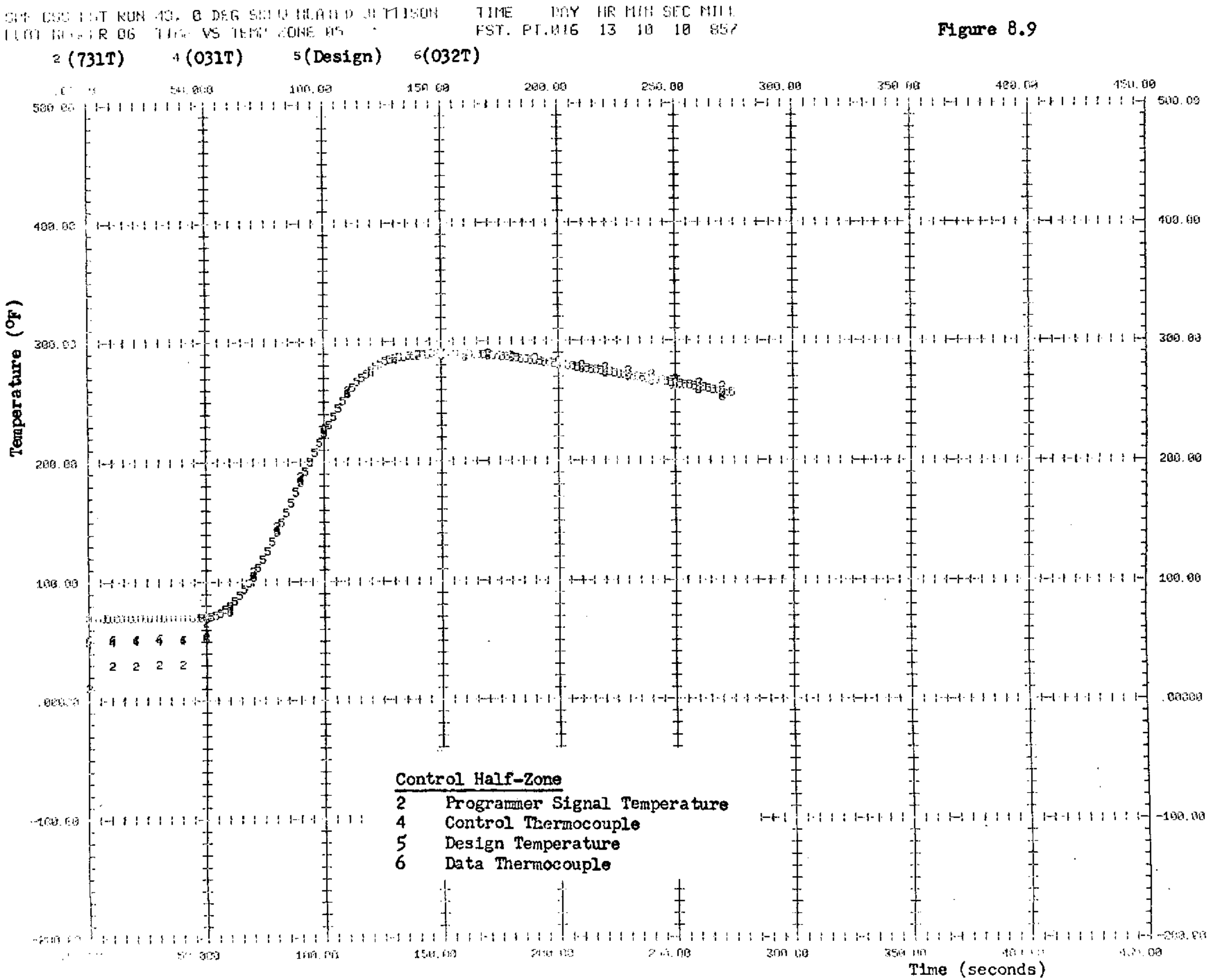
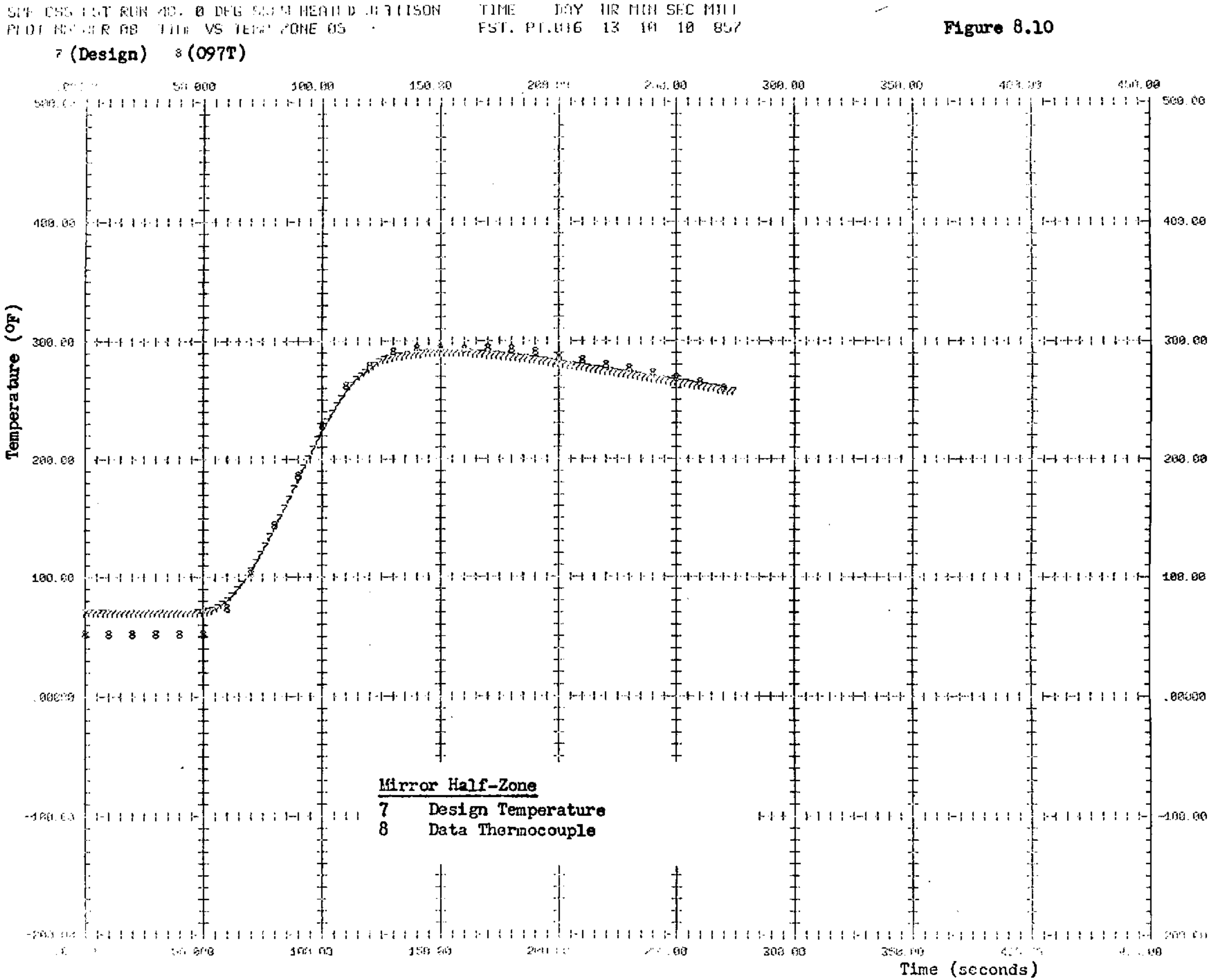

2 (731T)
4 (031T)
5 (Design)
6 (032T)
Temperature (°F)
Time (seconds)
Control Half-Zone
2 Programmer Signal Temperature
4 Control Thermocouple
5 Design Temperature
6 Data Thermocouple

Figure 8.9

Figure 8.10



TIME DAY HR MIN SEC MILL
FST. PT. 13 10 10 857
7 (Design) 8 (097T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
7 Design Temperature
8 Data Thermocouple

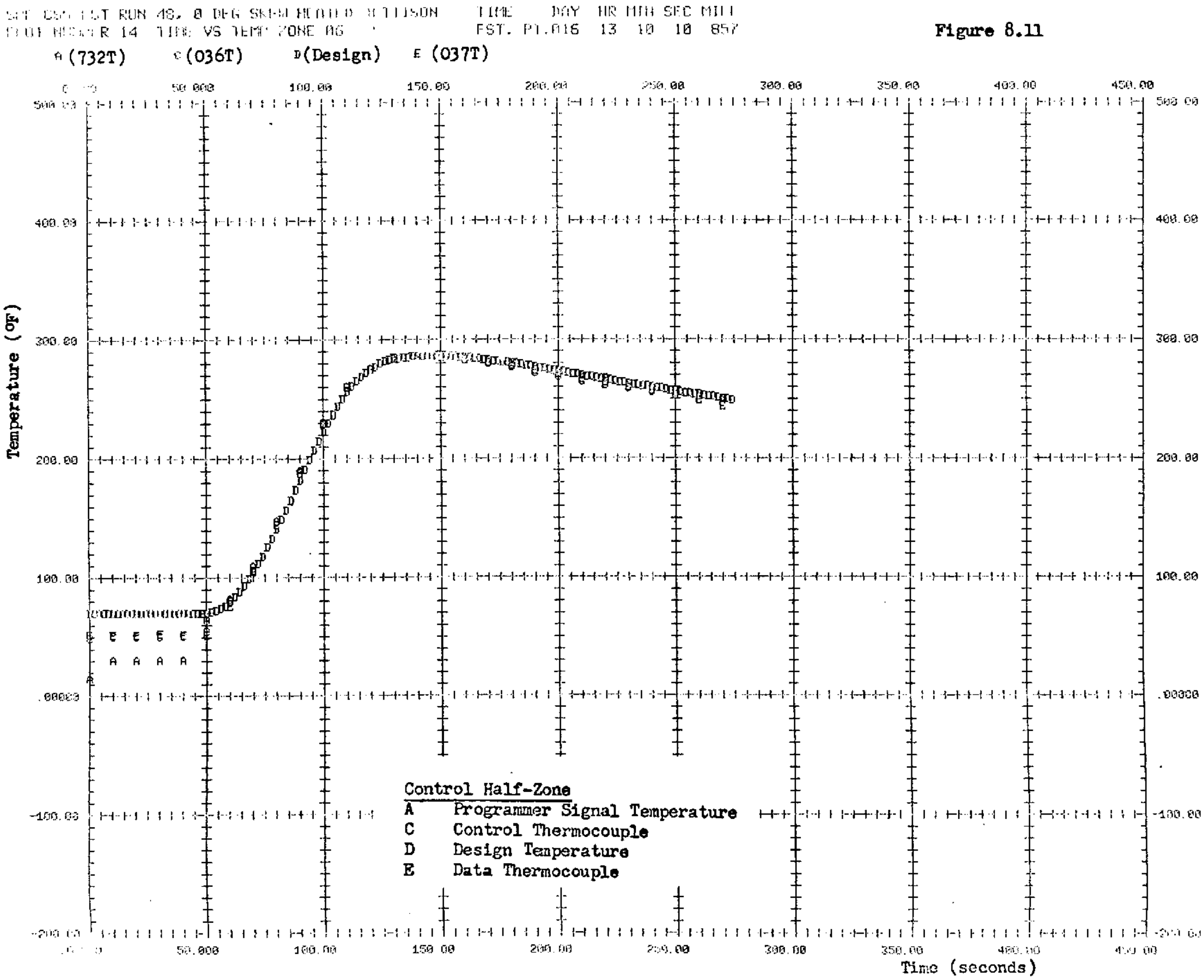
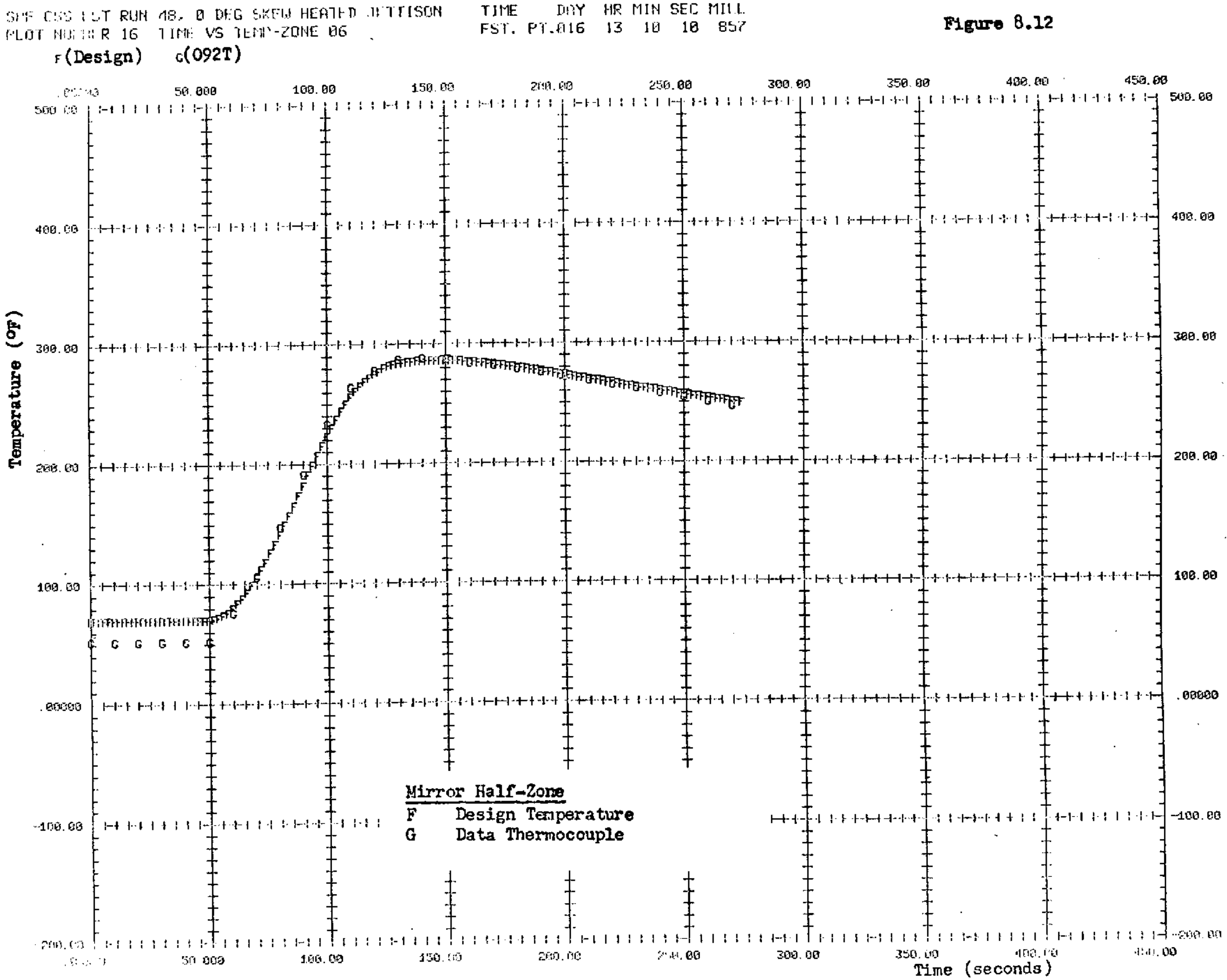
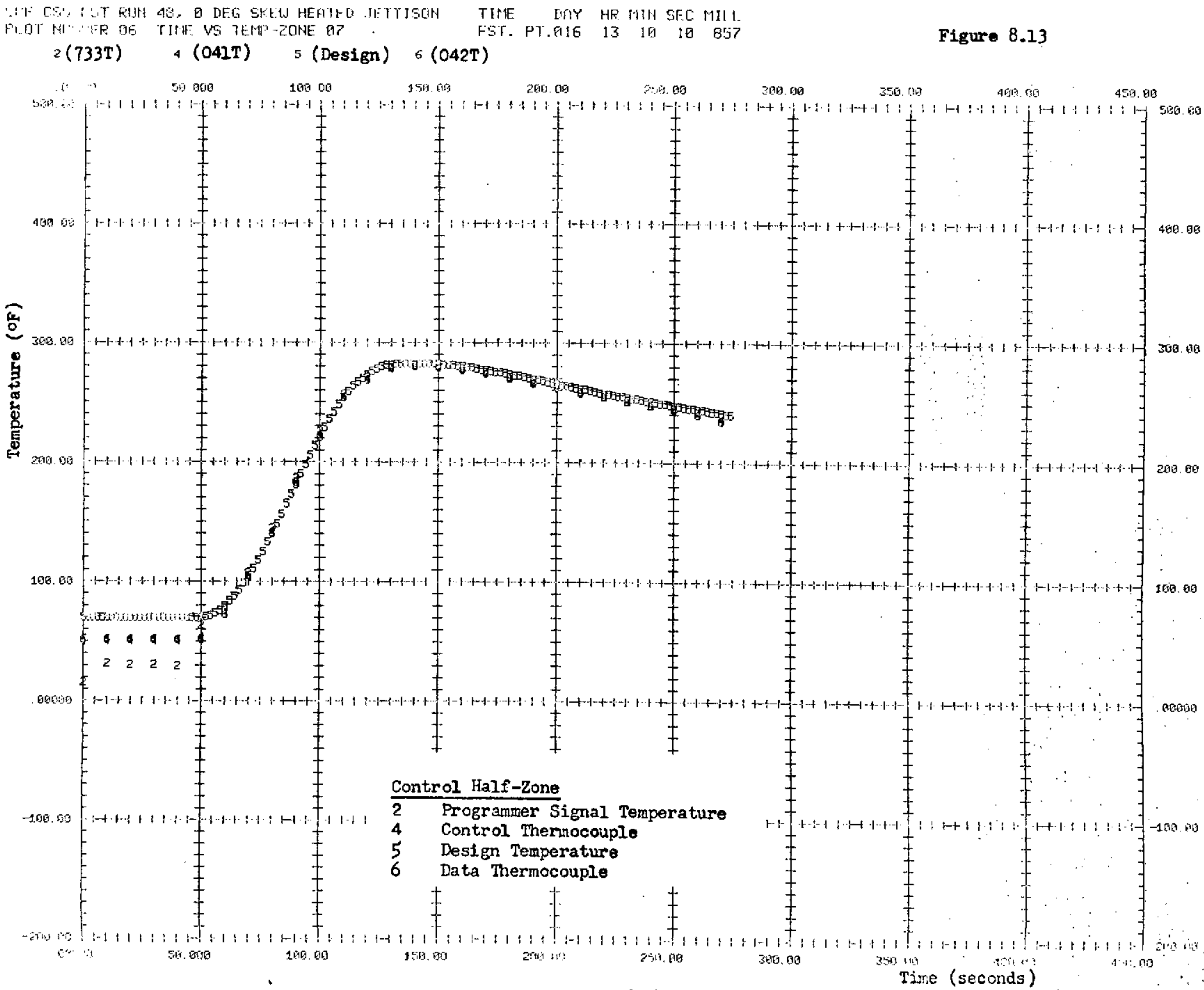

RUN 48, 0 DEG
R 14 TIME VS TEMP ZONE A6
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
A (732T) C (036T) D (Design) E (037T)
Temperature (°F)
Time (seconds)
Control Half-Zone
A Programmer Signal Temperature
C Control Thermocouple
D Design Temperature
E Data Thermocouple

Figure 8.11

Figure 8.12


SMF CSS TEST RUN 48, 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 16 TIME VS TEMP-ZONE 06
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
F(Design) G(092T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
F Design Temperature
G Data Thermocouple



PLOT NUMBER 06 TIME VS TEMP-ZONE 07
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
2 (733T) 4 (041T) 5 (Design) 6 (042T)
Temperature (oF)
Time (seconds)
Control Half-Zone
2 Programmer Signal Temperature
4 Control Thermocouple
5 Design Temperature
6 Data Thermocouple

Figure 8.13

SPF CSS TST RUN 48, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 08 TIME VS TEMP ZONE 07   TST. PT.016 13 10 18 857

Figure 8.14

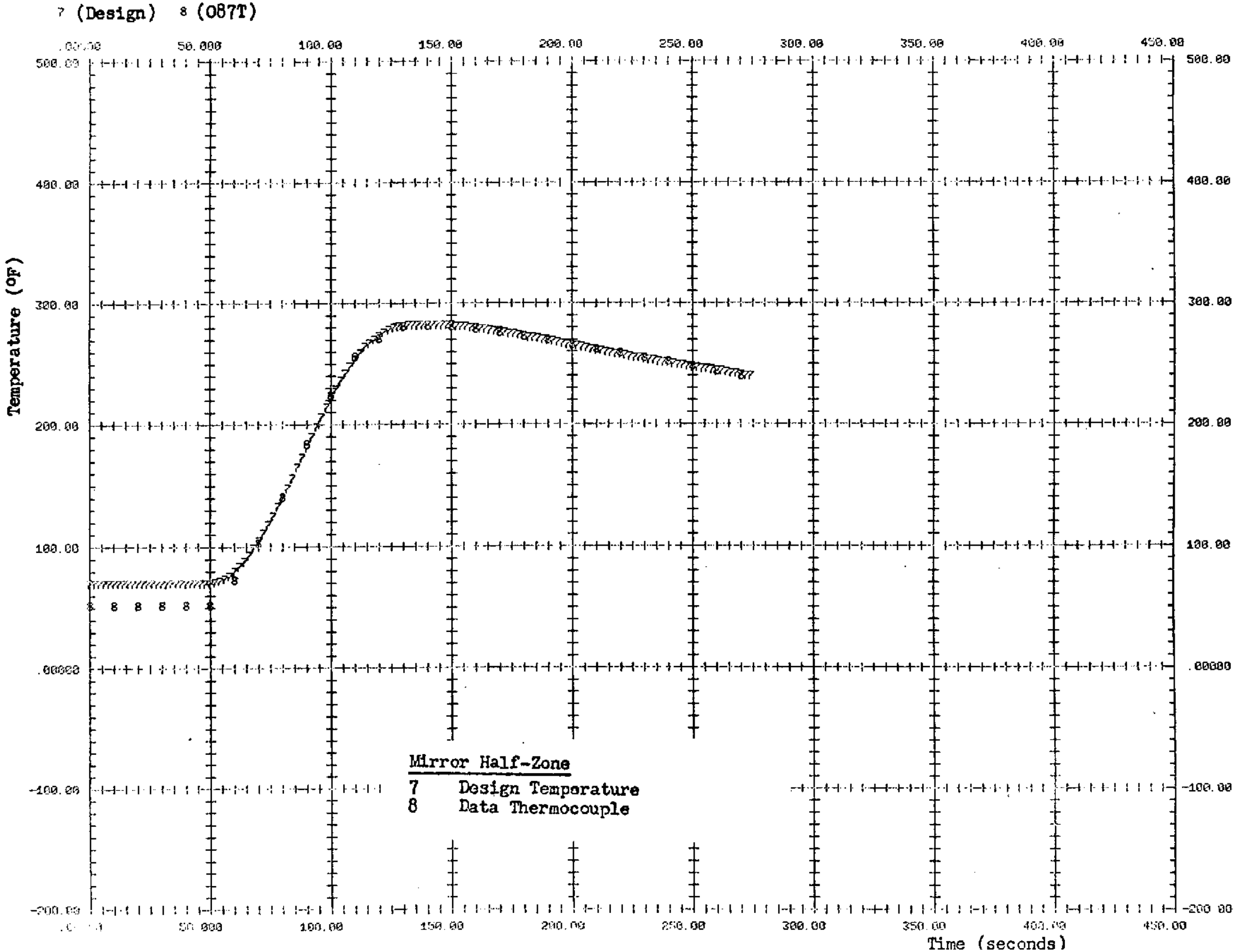
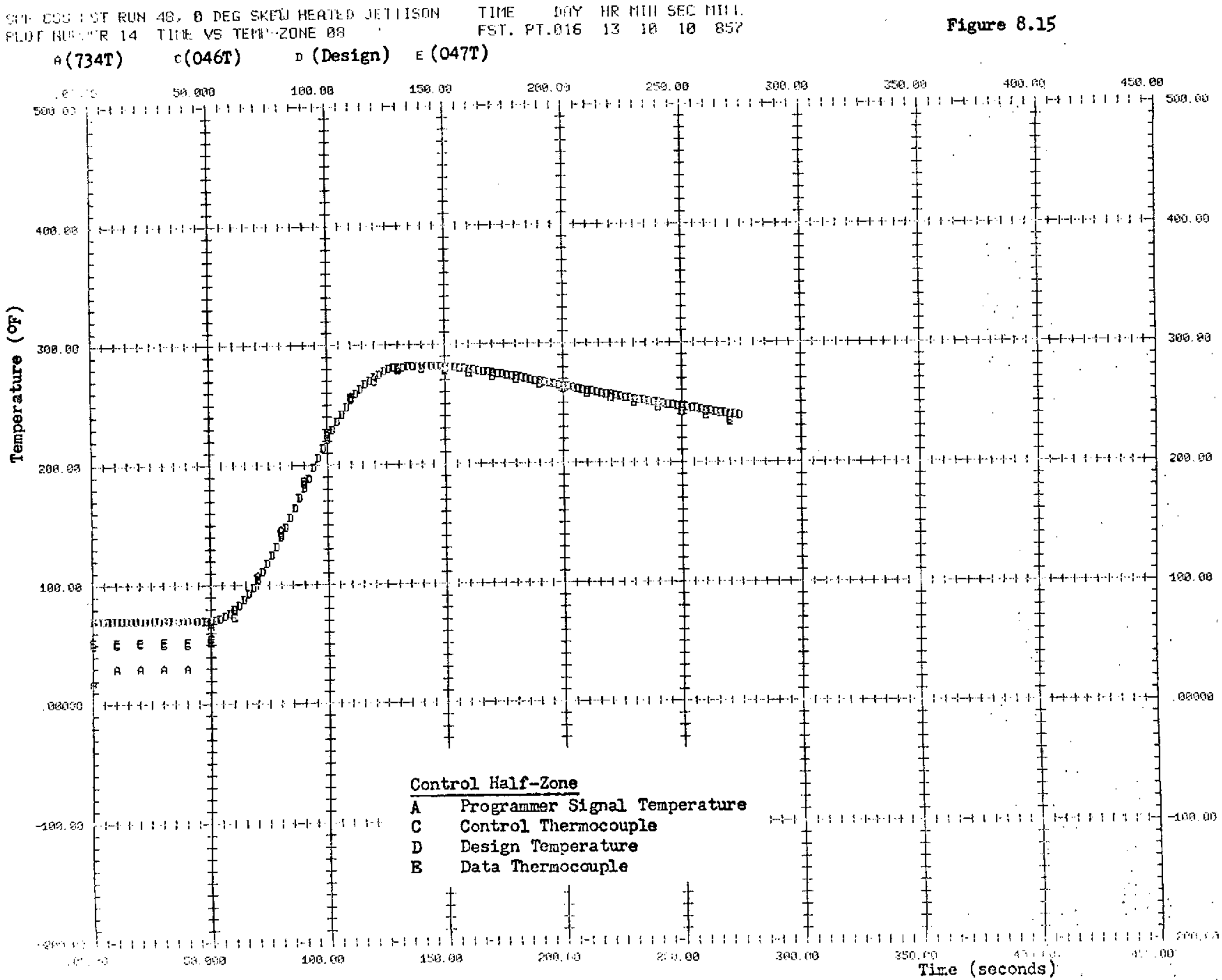
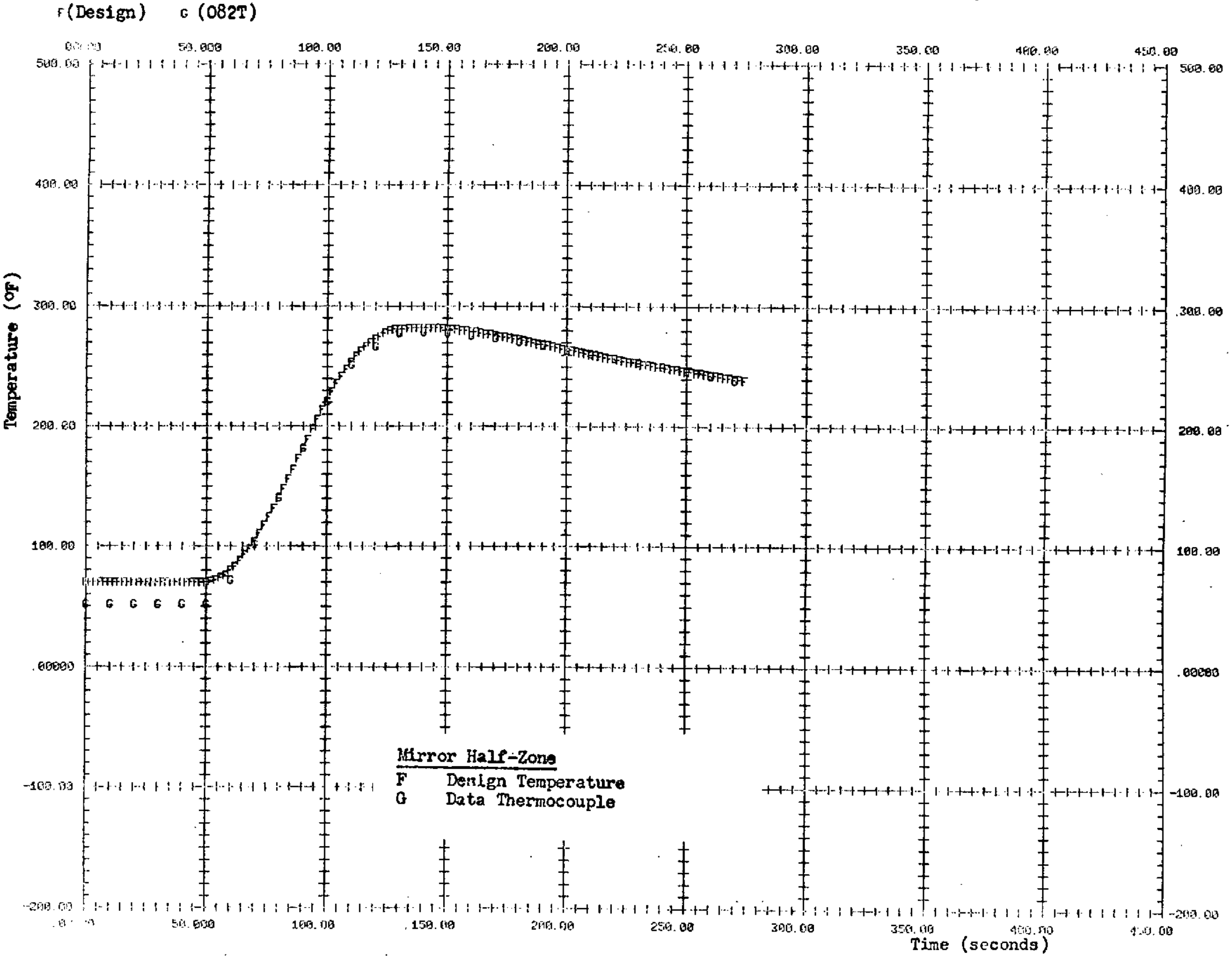


Figure 8.15


SRM CSS TEST RUN 48, 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 14 TIME VS TEMP-ZONE 08
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
A (734T)
C (046T)
D (Design)
E (047T)
Temperature (°F)
Time (seconds)
Control Half-Zone
A Programmer Signal Temperature
C Control Thermocouple
D Design Temperature
E Data Thermocouple

SMF CSC TEST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 16 TIME VS TEMP-ZONE 08 FST. PT.016 13 10 10 857

Figure 8.16



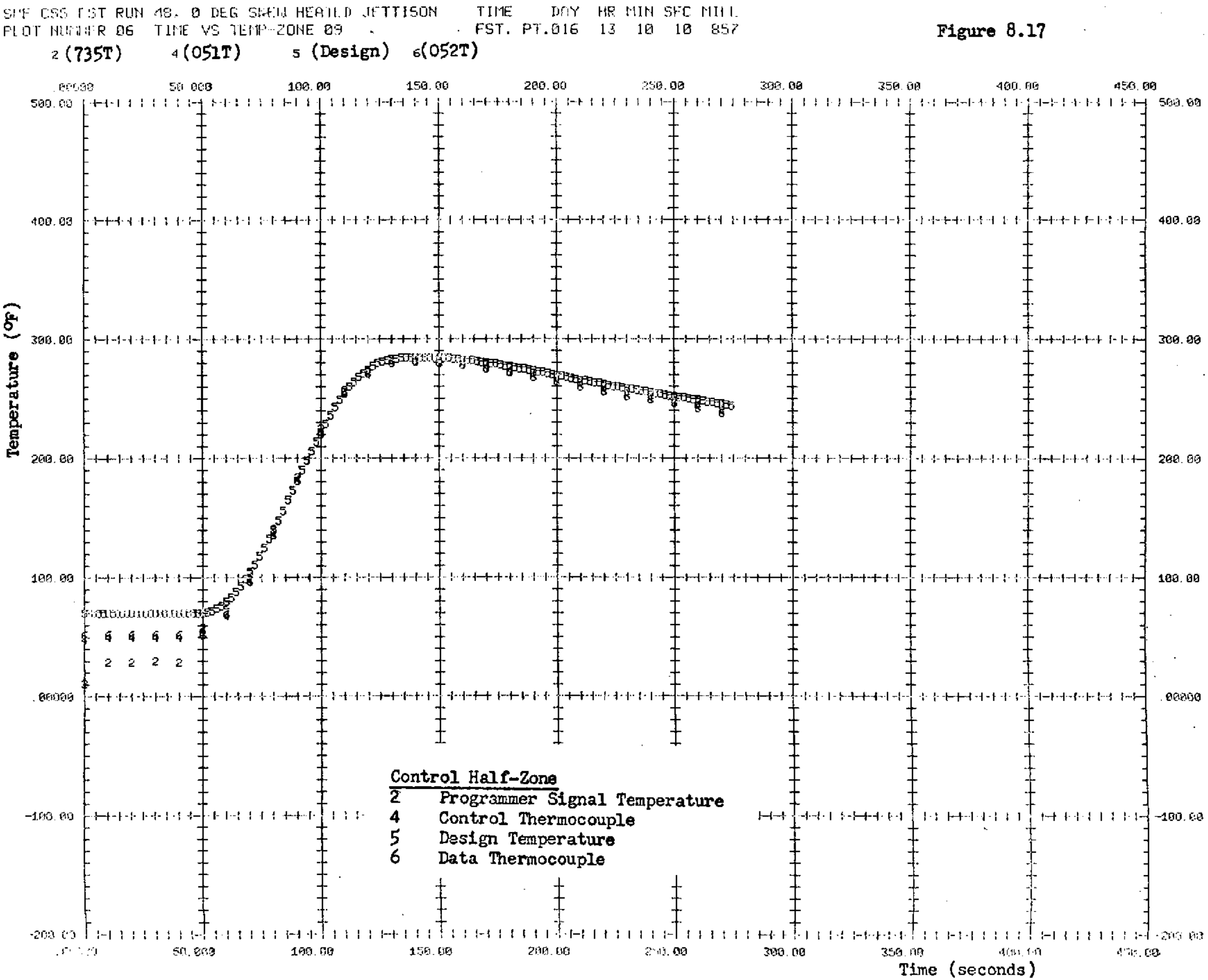
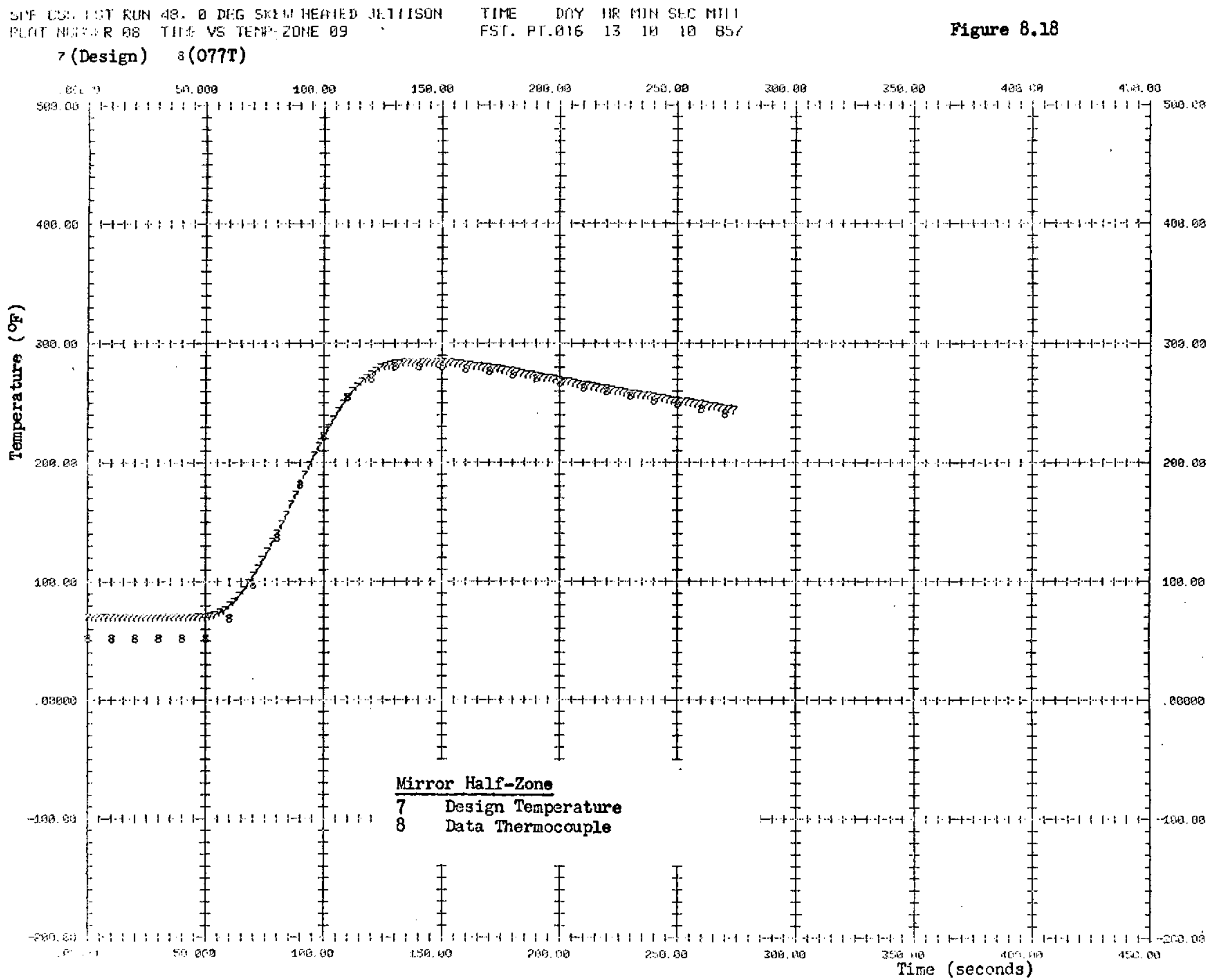

SMF CSS FST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 TIME VS TEMP-ZONE 09 FST. PT.016 13 10 10 857
2 (735T) 4 (051T) 5 (Design) 6(052T)
Temperature (°F)
Time (seconds)
Control Half-Zone
2 Programmer Signal Temperature
4 Control Thermocouple
5 Design Temperature
6 Data Thermocouple

Figure 8.17

Figure 8.18



SPF CSS TST RUN 48. 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 08 TIME VS TEMP-ZONE 09
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
7 (Design) 8 (077T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
7 Design Temperature
8 Data Thermocouple

SPF CSS TST RUN 48. 0 DEG SMPU HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 14 TIME VS TEMP ZONE 10 FST. PT.016 13 10 10 857

Figure 8.19

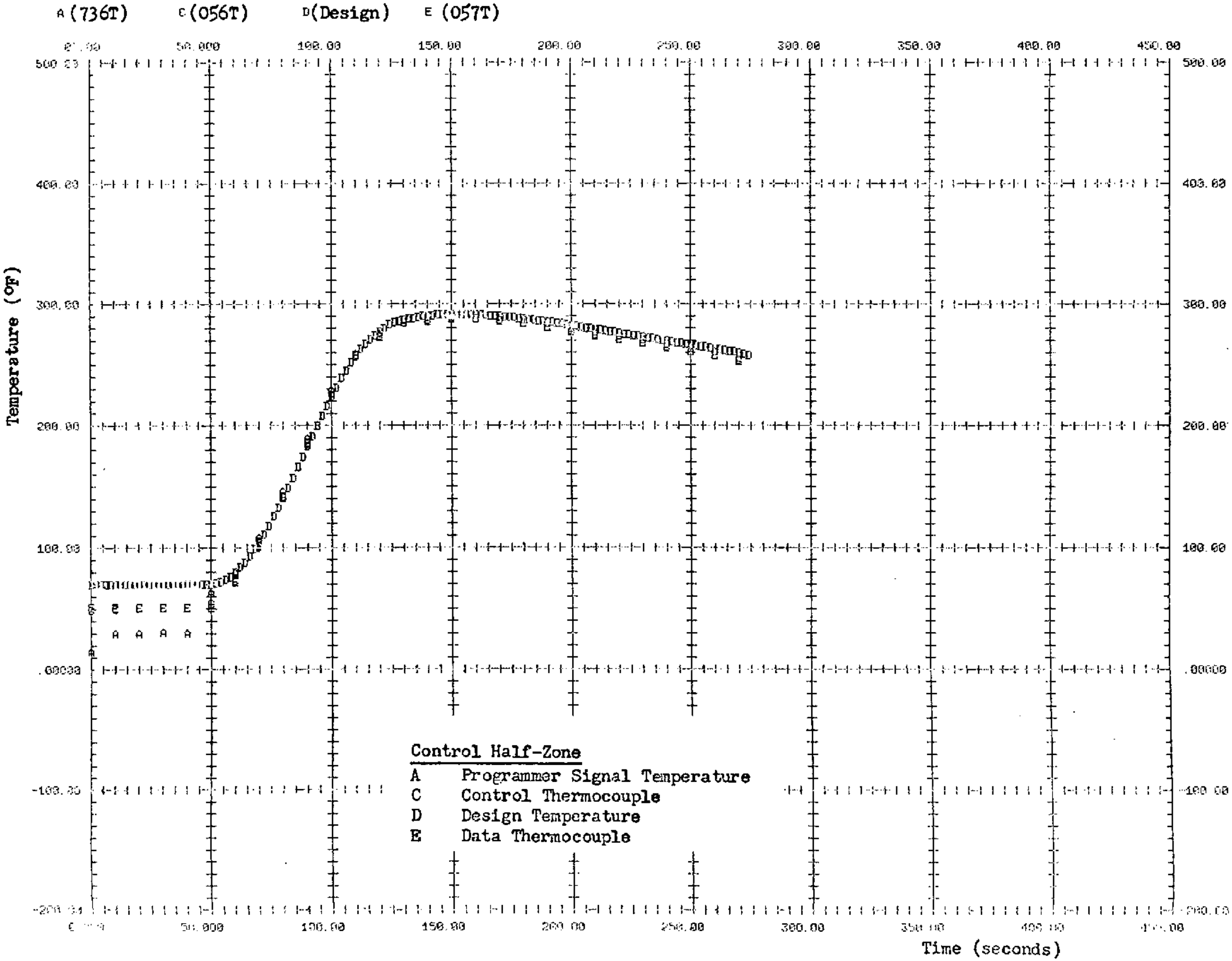
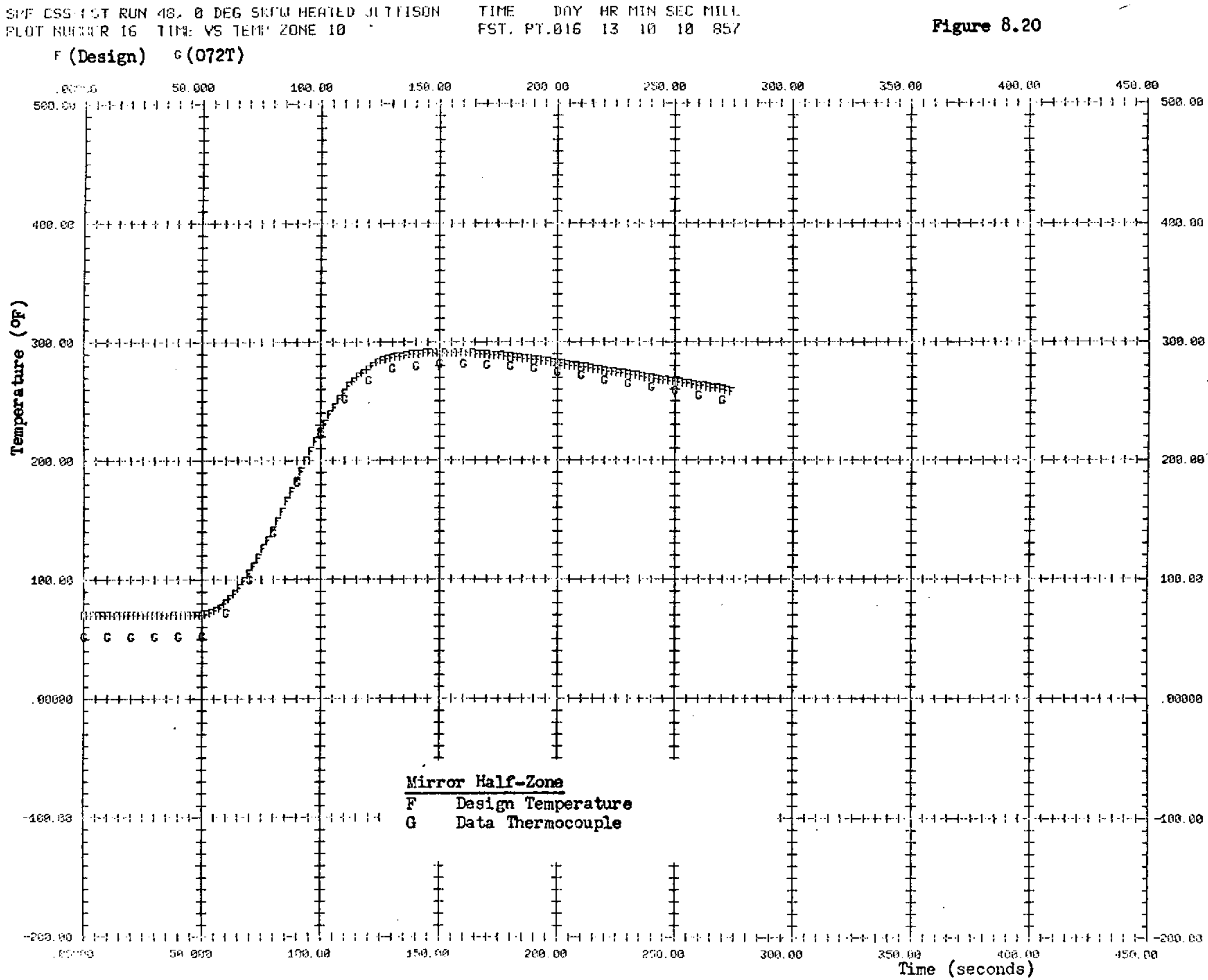


Figure 8.20

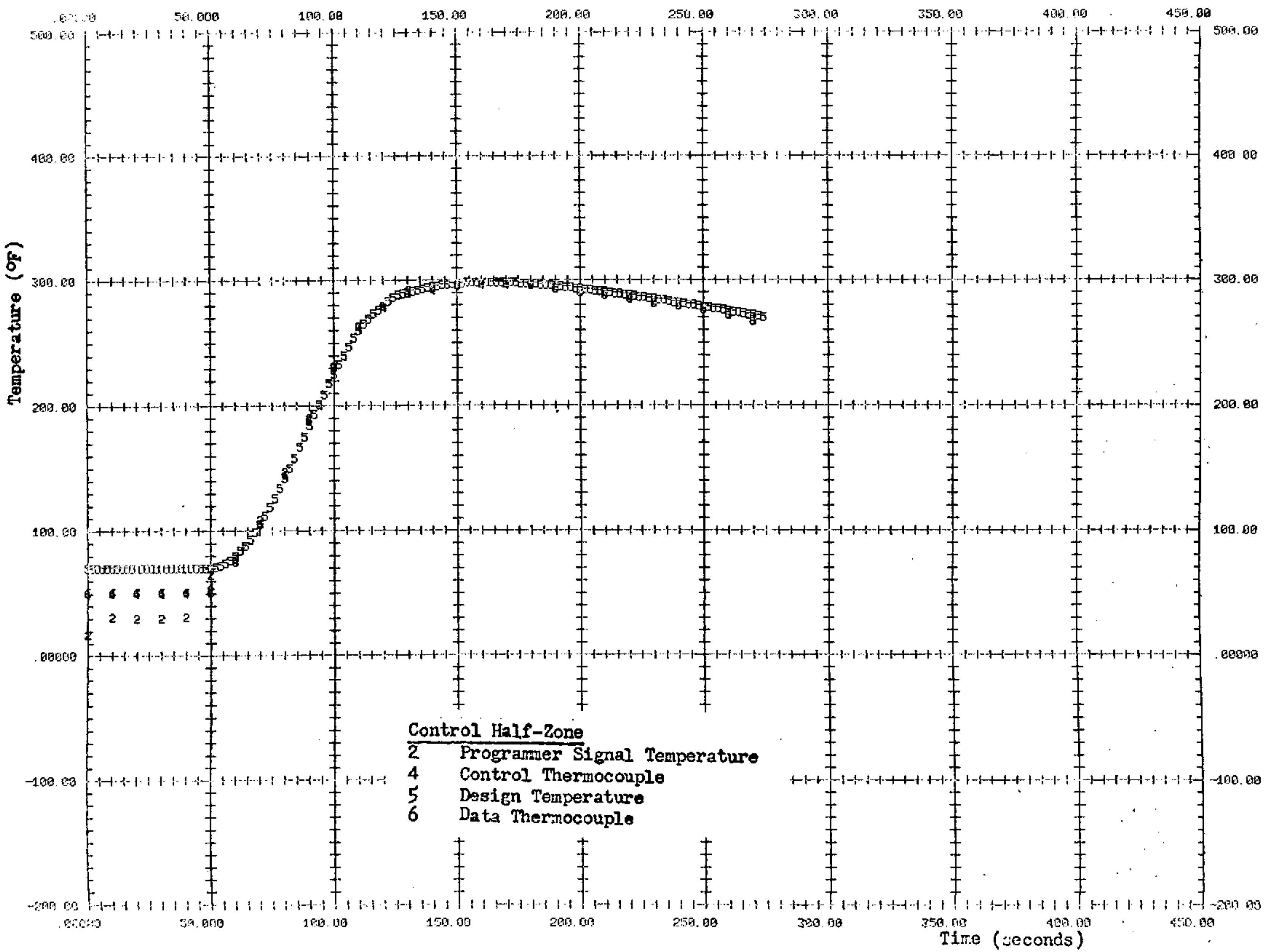


SRF CSS-1ST RUN 48, 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 16 TIME VS TEMP ZONE 10
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
F (Design) G (072T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
F Design Temperature
G Data Thermocouple

SMF CSS TST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 TIME VS TEMP ZONE 11 FST. PT.016 13 10 10 857

2 (737T) 4 (066T) 5 (Design) 6 (067T)

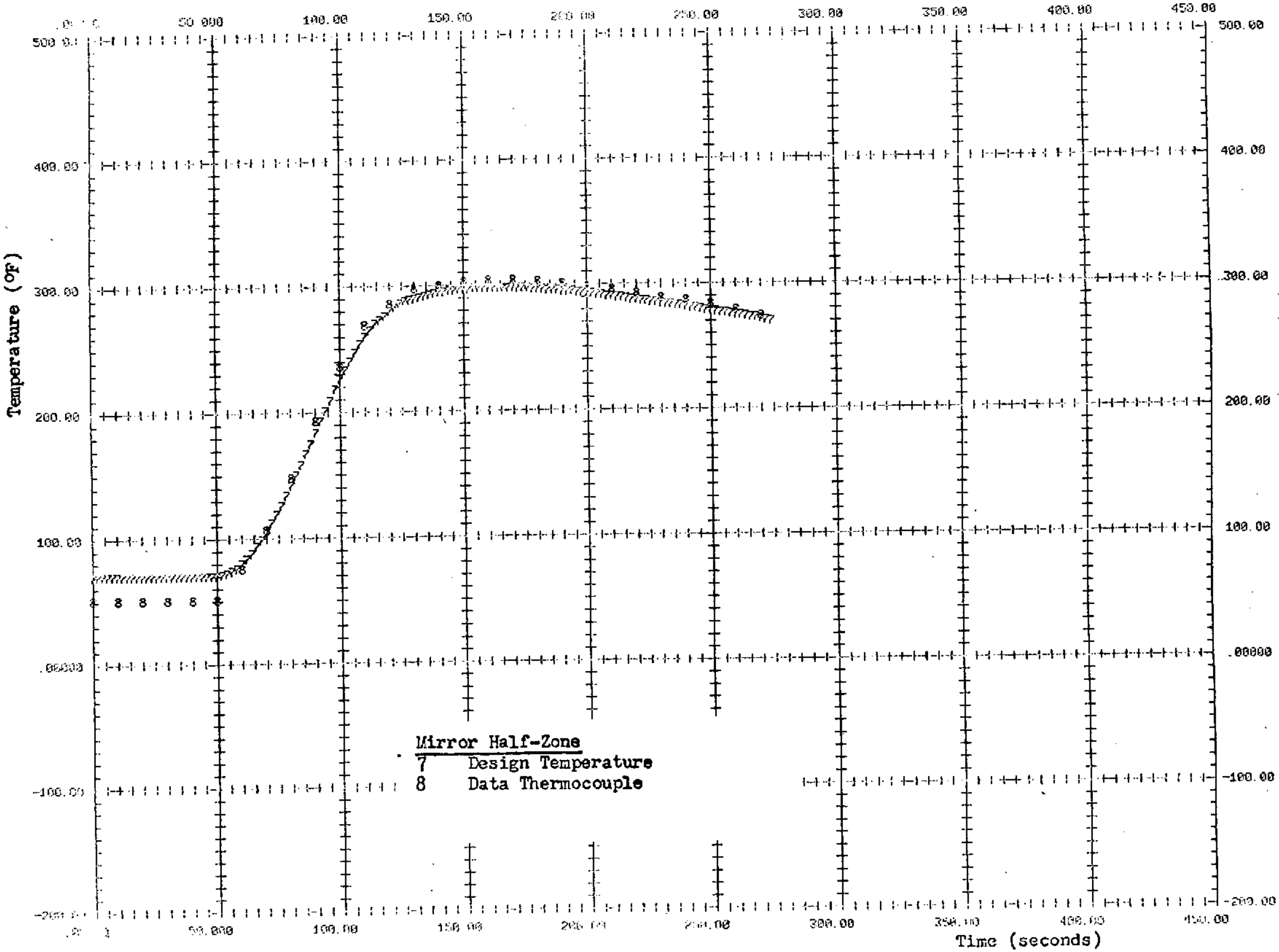
Figure 8.21

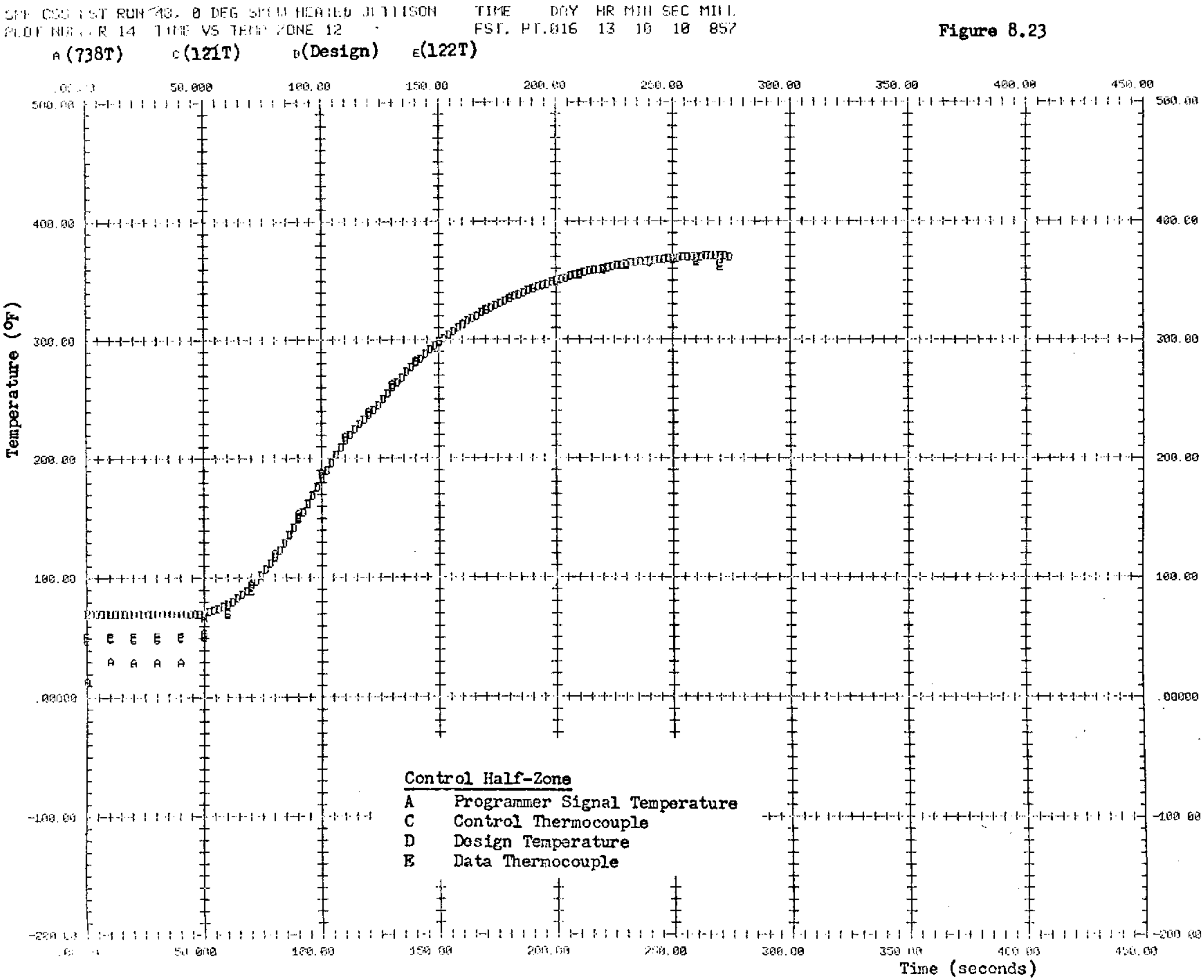


SMF CSG TEST RUN 40. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 08 TIME VS TEMP ZONE 11 FST. PT.016 13 10 10 857

Figure 8.22

7 (Design) 8 (062T)





TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
A (738T)
C (121T)
D (Design)
E (122T)
Temperature (°F)
Time (seconds)
Control Half-Zone
A Programmer Signal Temperature
C Control Thermocouple
D Design Temperature
E Data Thermocouple

Figure 8.23

Figure 8.24

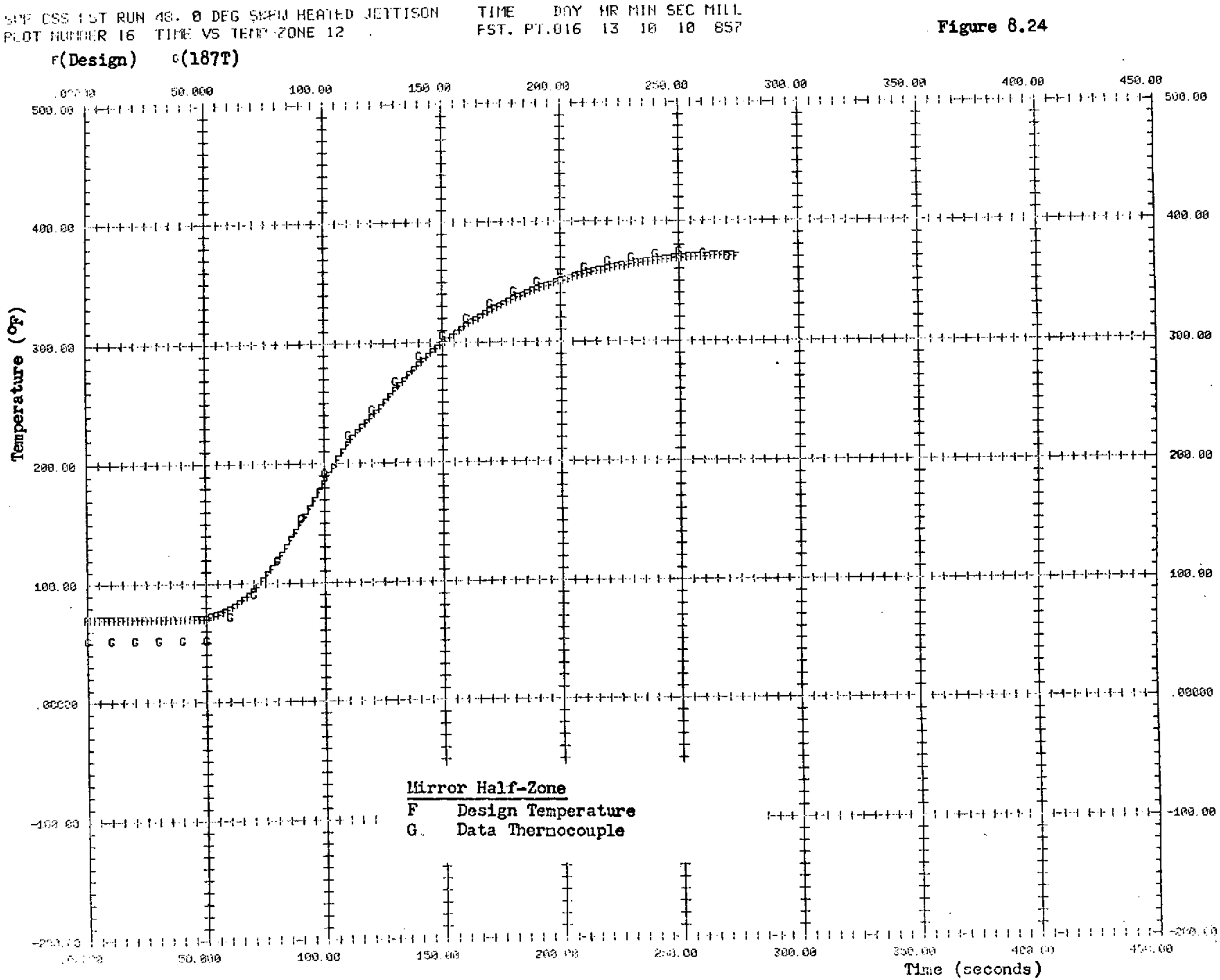

SMP CSS TST RUN 48. 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 16 TIME VS TEMP ZONE 12
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
F(Design) G(187T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
F Design Temperature
G. Data Thermocouple

Figure 8.25

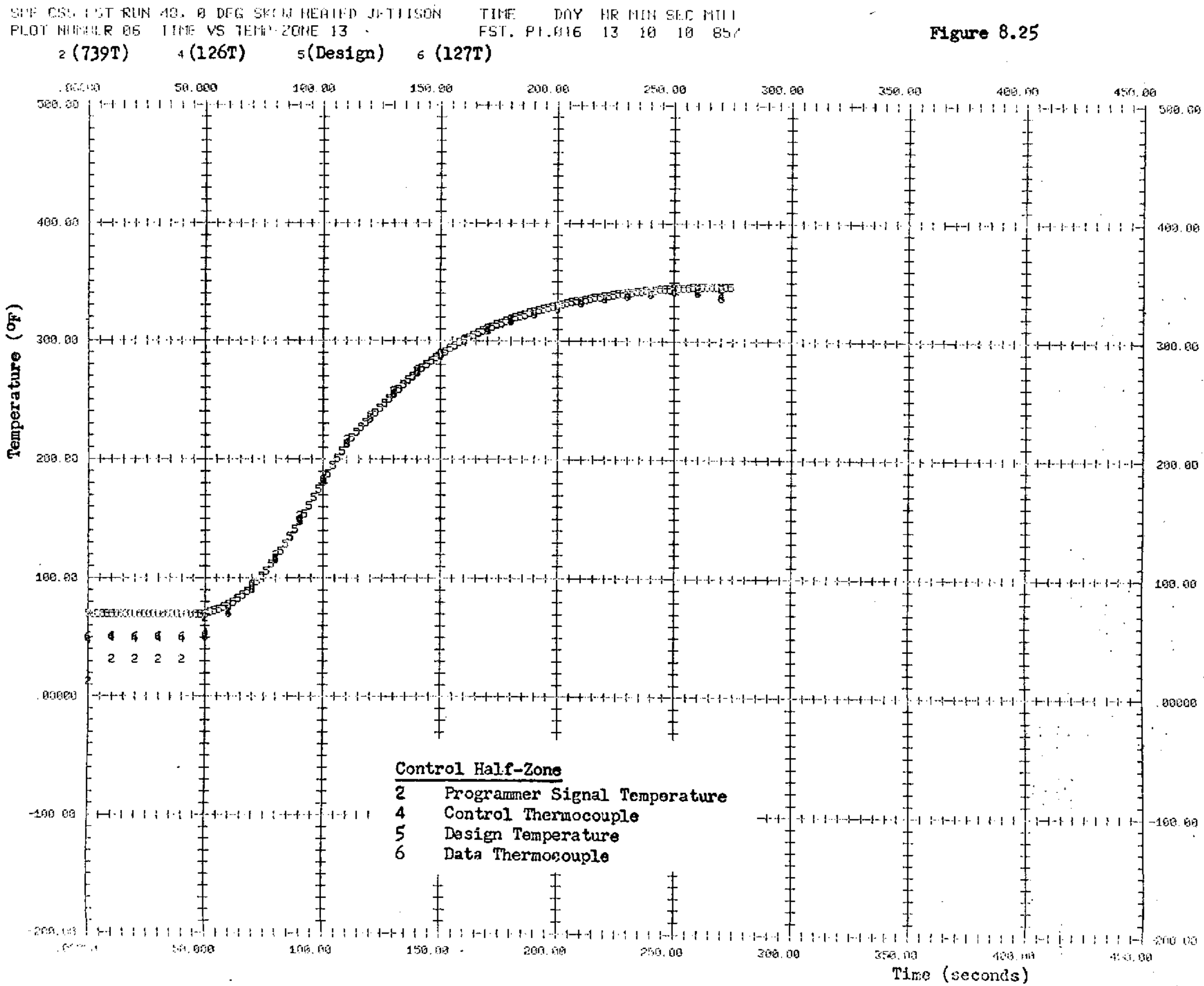
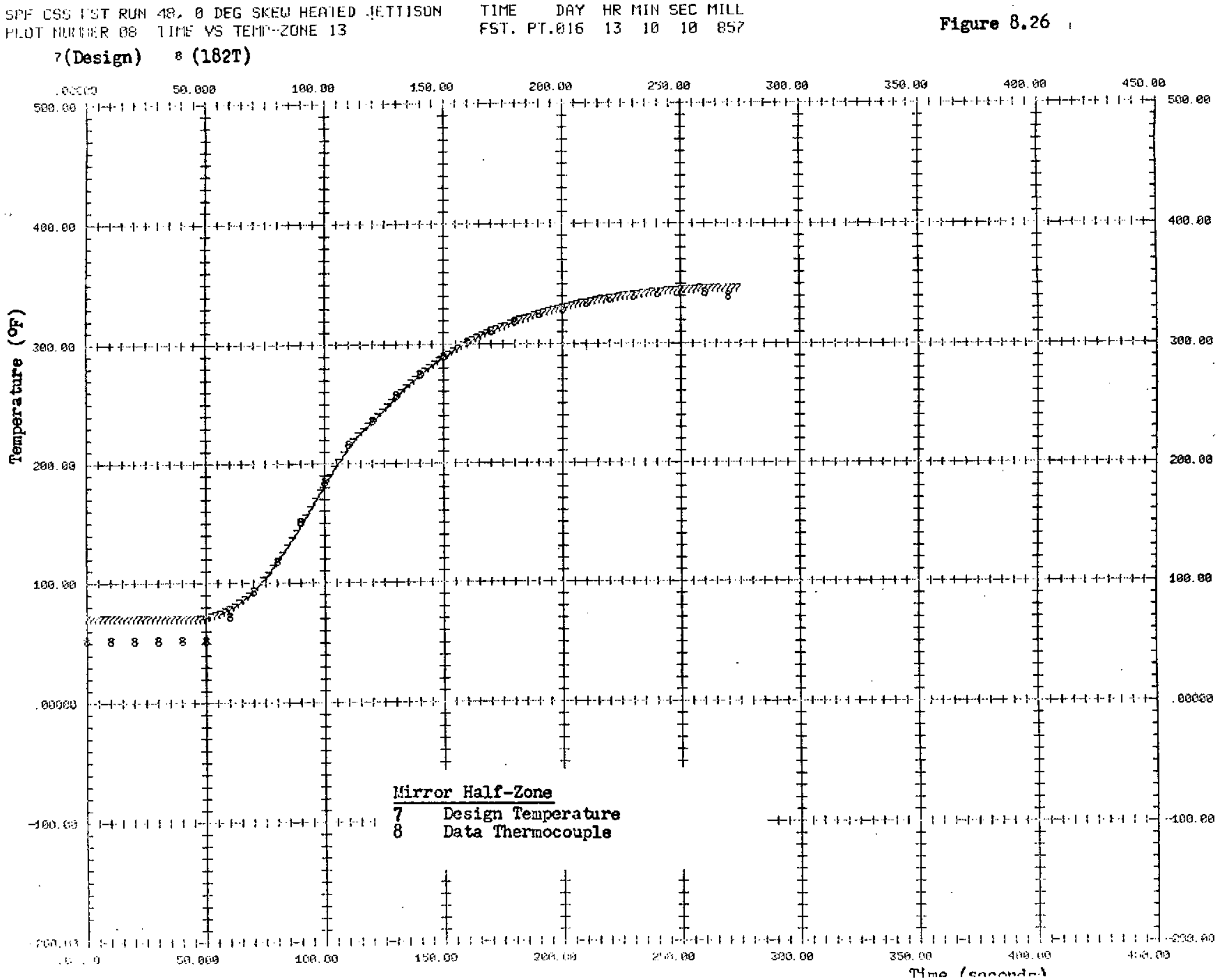
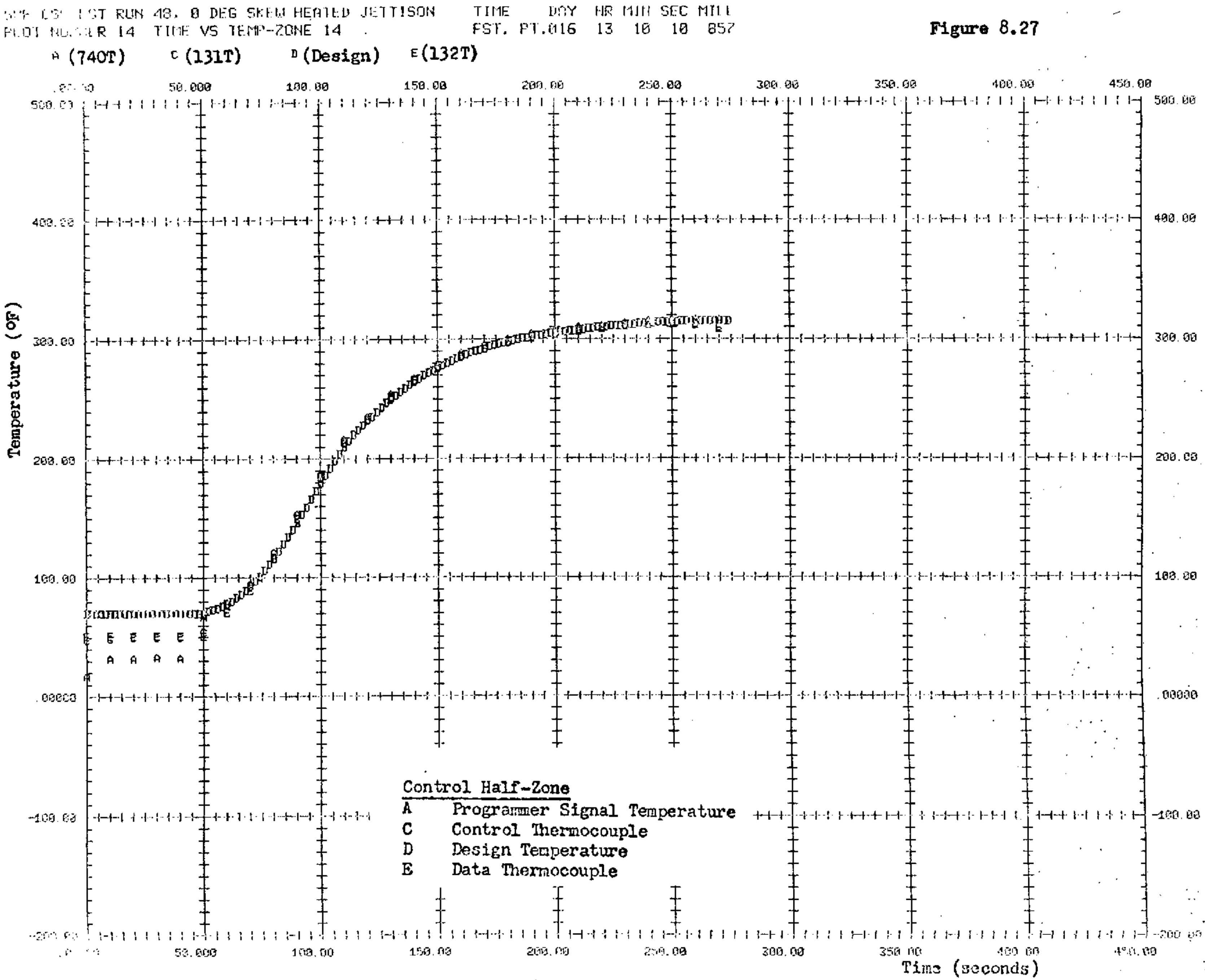

SPF CSS FST RUN 40, 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 06 TIME VS TEMP ZONE 13
TIME DAY HR MIN SEC MILL
FST. P1.016 13 10 10 857
2 (739T) 4 (126T) 5 (Design) 6 (127T)
Temperature (°F)
Time (seconds)
Control Half-Zone
2 Programmer Signal Temperature
4 Control Thermocouple
5 Design Temperature
6 Data Thermocouple

Figure 8.26



SPF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 08 TIME VS TEMP-ZONE 13
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
7 (Design) 8 (182T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
7 Design Temperature
8 Data Thermocouple

Figure 8.27

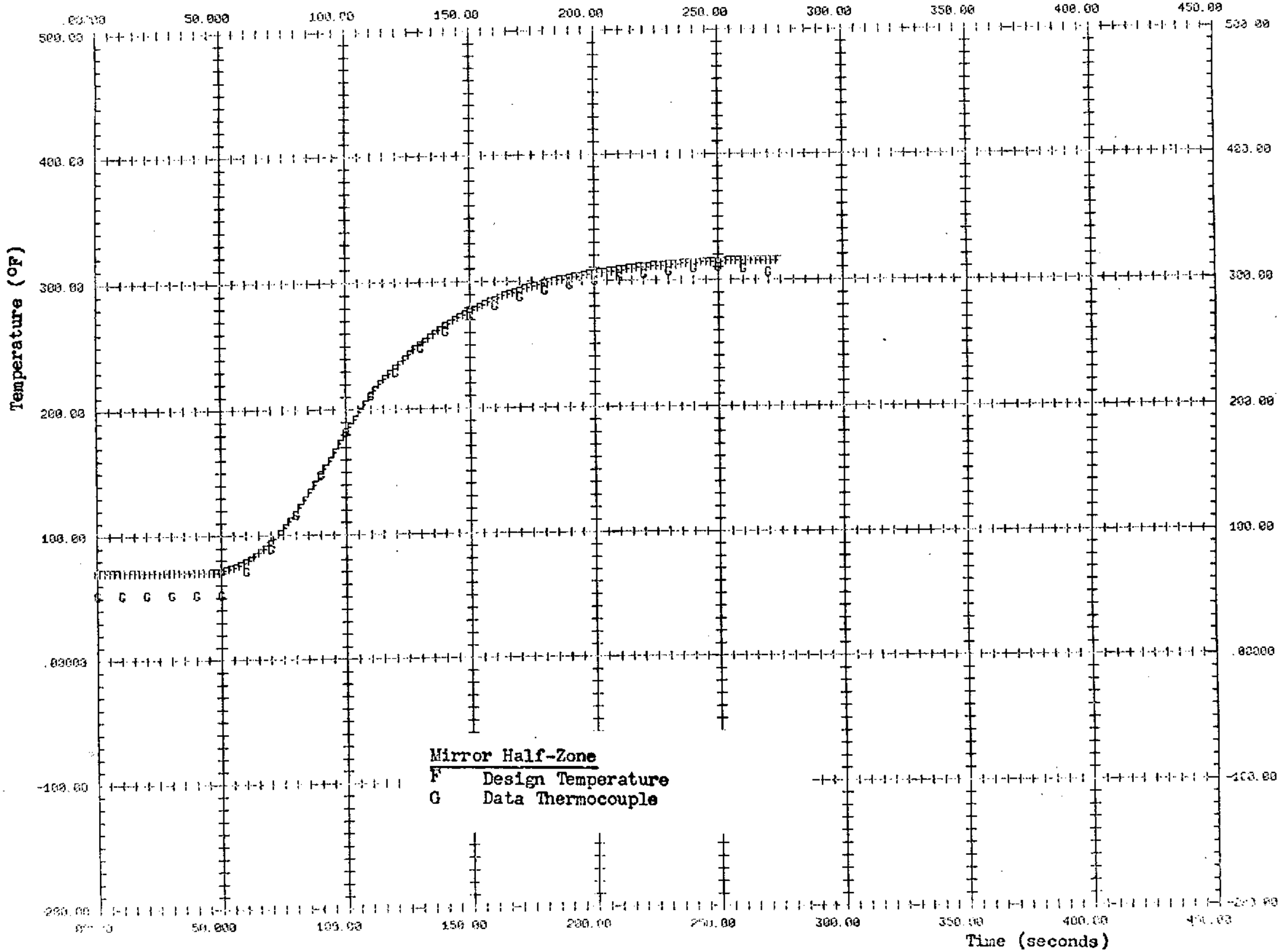


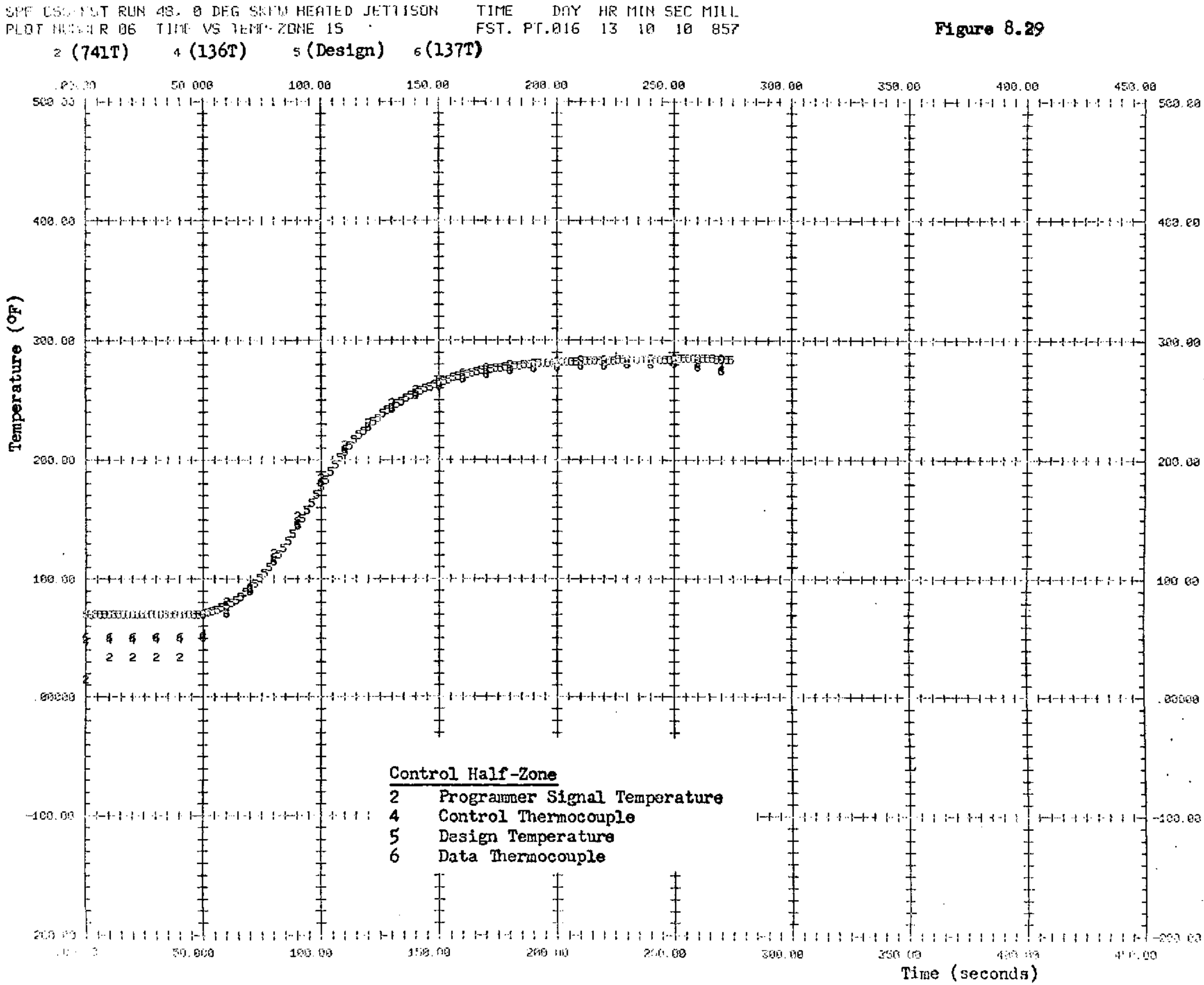
SMF CS TST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 14 TIME VS TEMP-ZONE 14 FST. PT.016 13 10 10 857
A (740T) C (131T) D (Design) E (132T)
Temperature (°F)
Time (seconds)
Control Half-Zone
A Programmer Signal Temperature
C Control Thermocouple
D Design Temperature
E Data Thermocouple

Figure 8.28

SPF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL.
PLOT NUMBER 16 TIME VS TEMP-ZONE 14 .   FST. PT.016 13 10 10 857

F (Design) G (177T)




SPF CSS-FST RUN 48. 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 06 TIME VS TEMP-ZONE 15
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
2 (741T) 4 (136T) 5 (Design) 6 (137T)
Temperature (°F)
Time (seconds)
Control Half-Zone
2 Programmer Signal Temperature
4 Control Thermocouple
5 Design Temperature
6 Data Thermocouple
Figure 8.29

SMF CSG EST RUN 48. 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 08 TIME VS TEMP ZONE 15   FST. PT.016 13 10 10 857

Figure 8.30

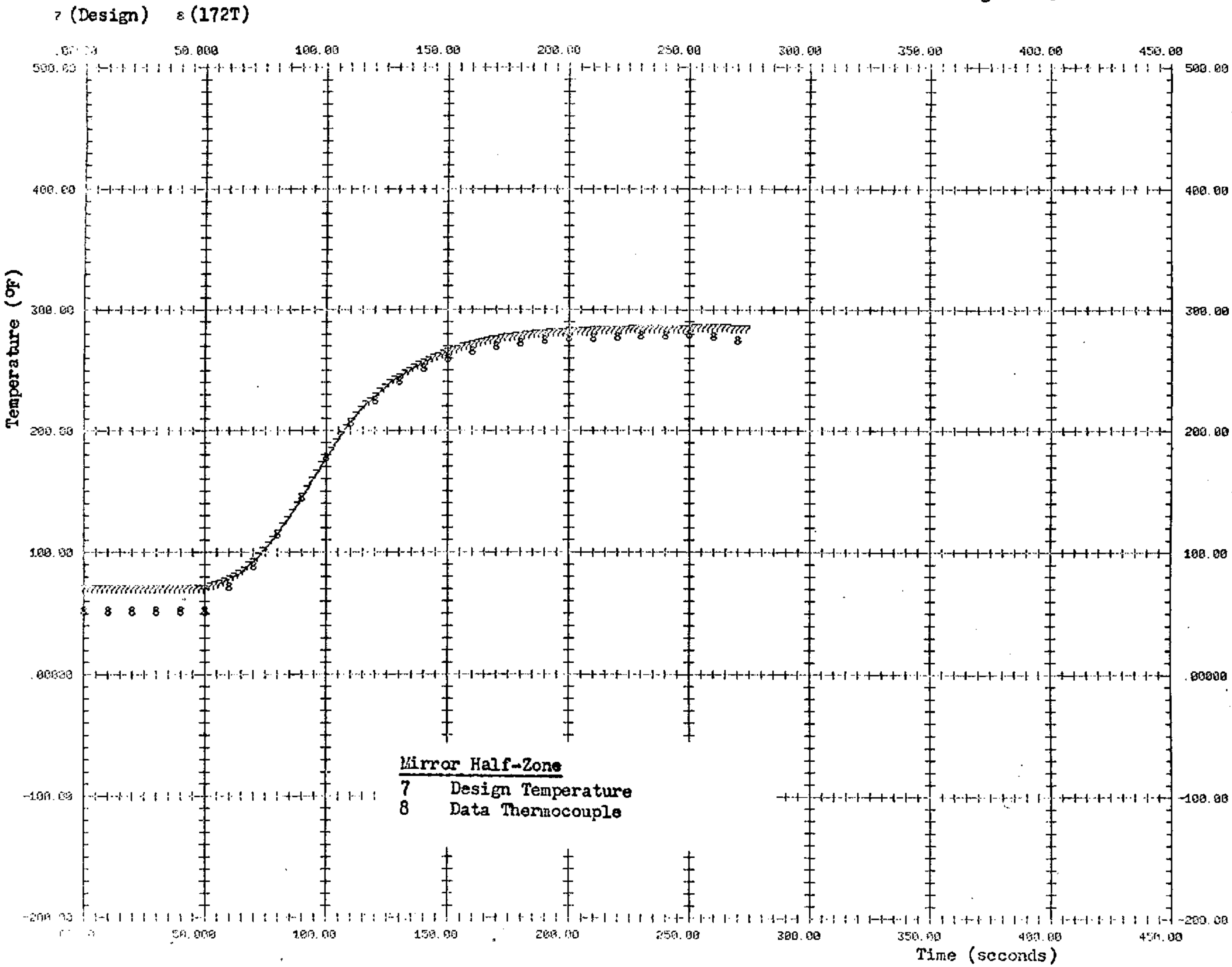
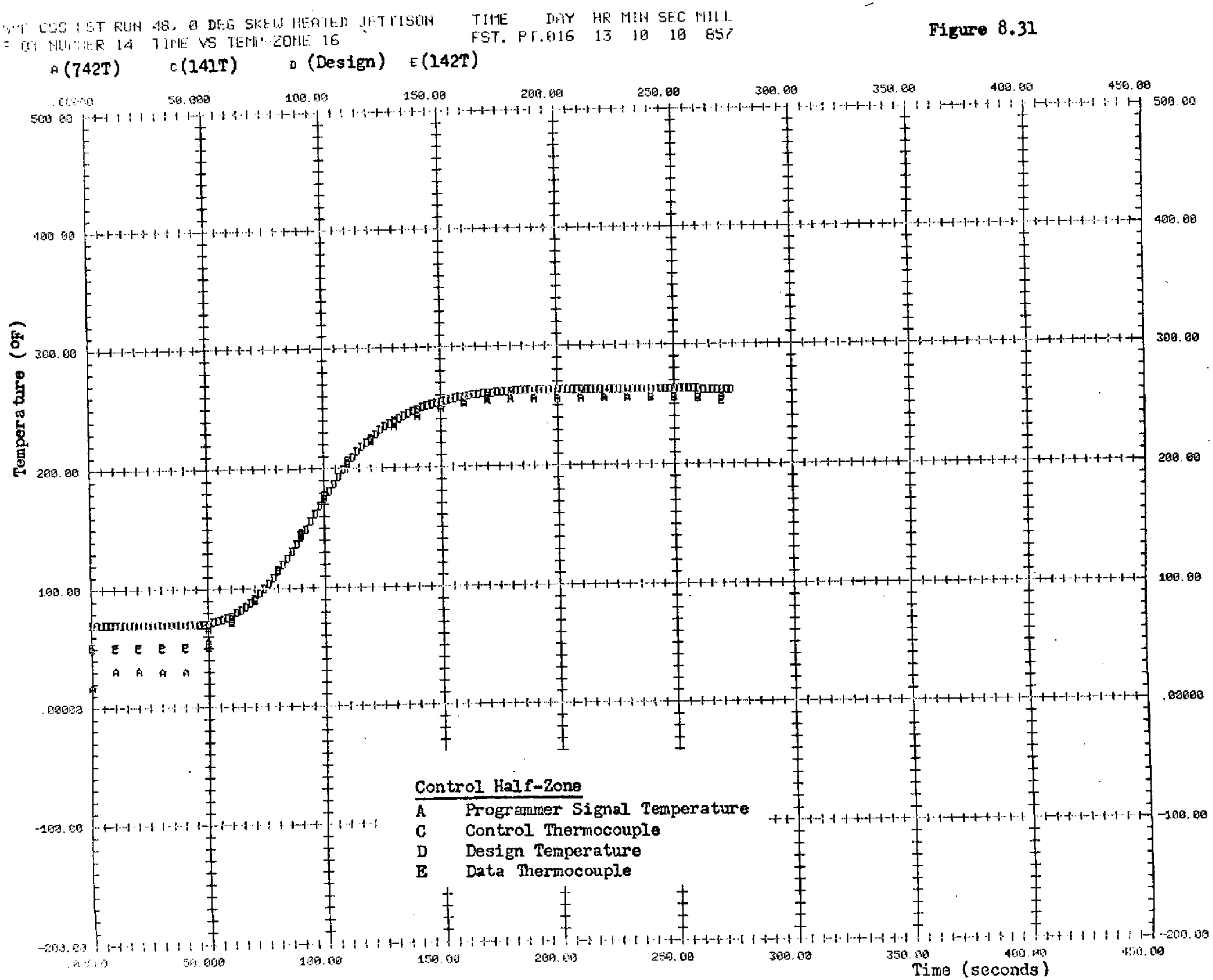


Figure 8.31



SMT CSG TST RUN 48, 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 14 TIME VS TEMP ZONE 16
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
A (742T) C (141T) D (Design) E (142T)
Temperature (°F)
Time (seconds)
Control Half-Zone
A Programmer Signal Temperature
C Control Thermocouple
D Design Temperature
E Data Thermocouple

SRF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 16 TIME VS TEMP-ZONE 16   FST. PT.016 13 10 10 857

Figure 8.32

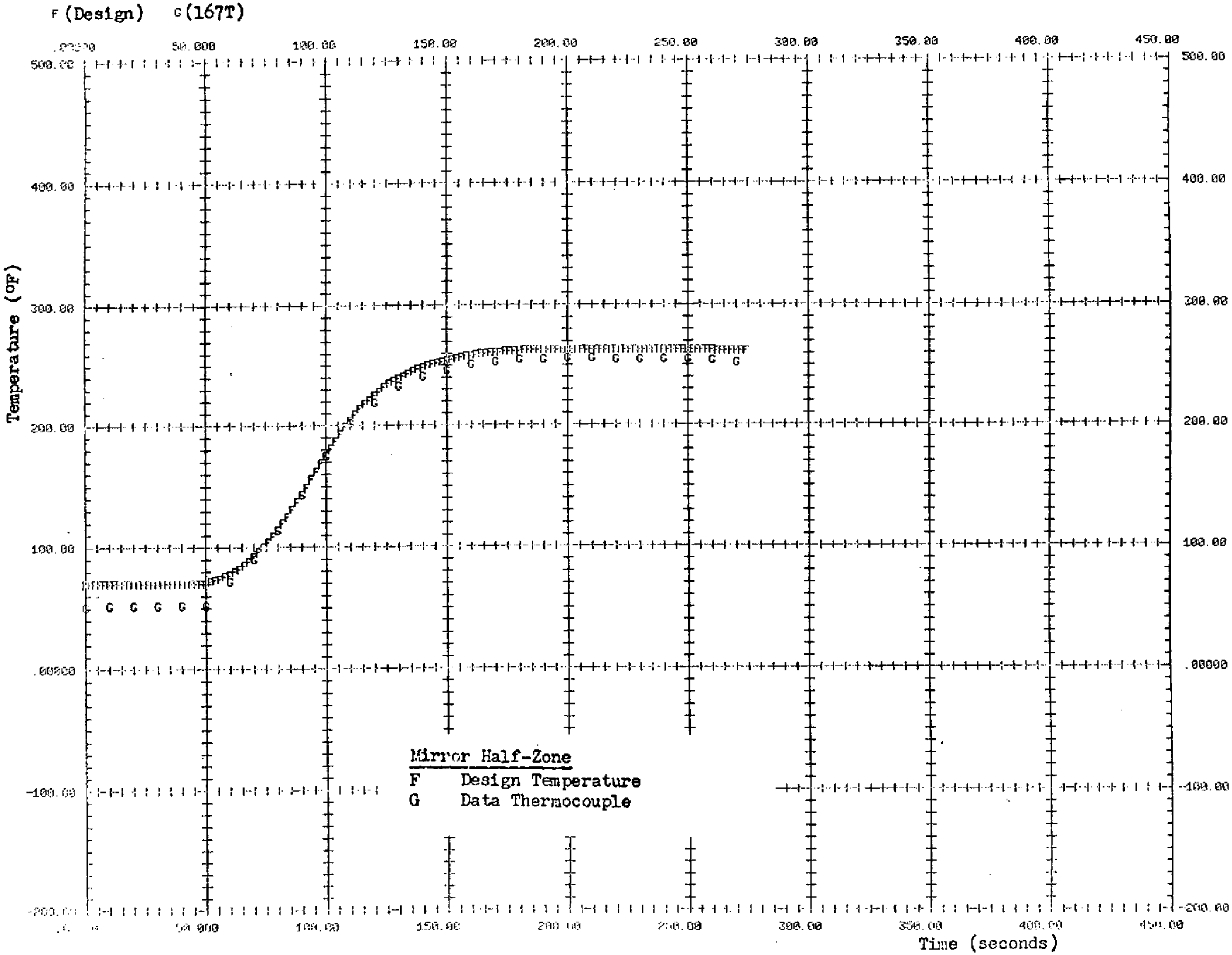
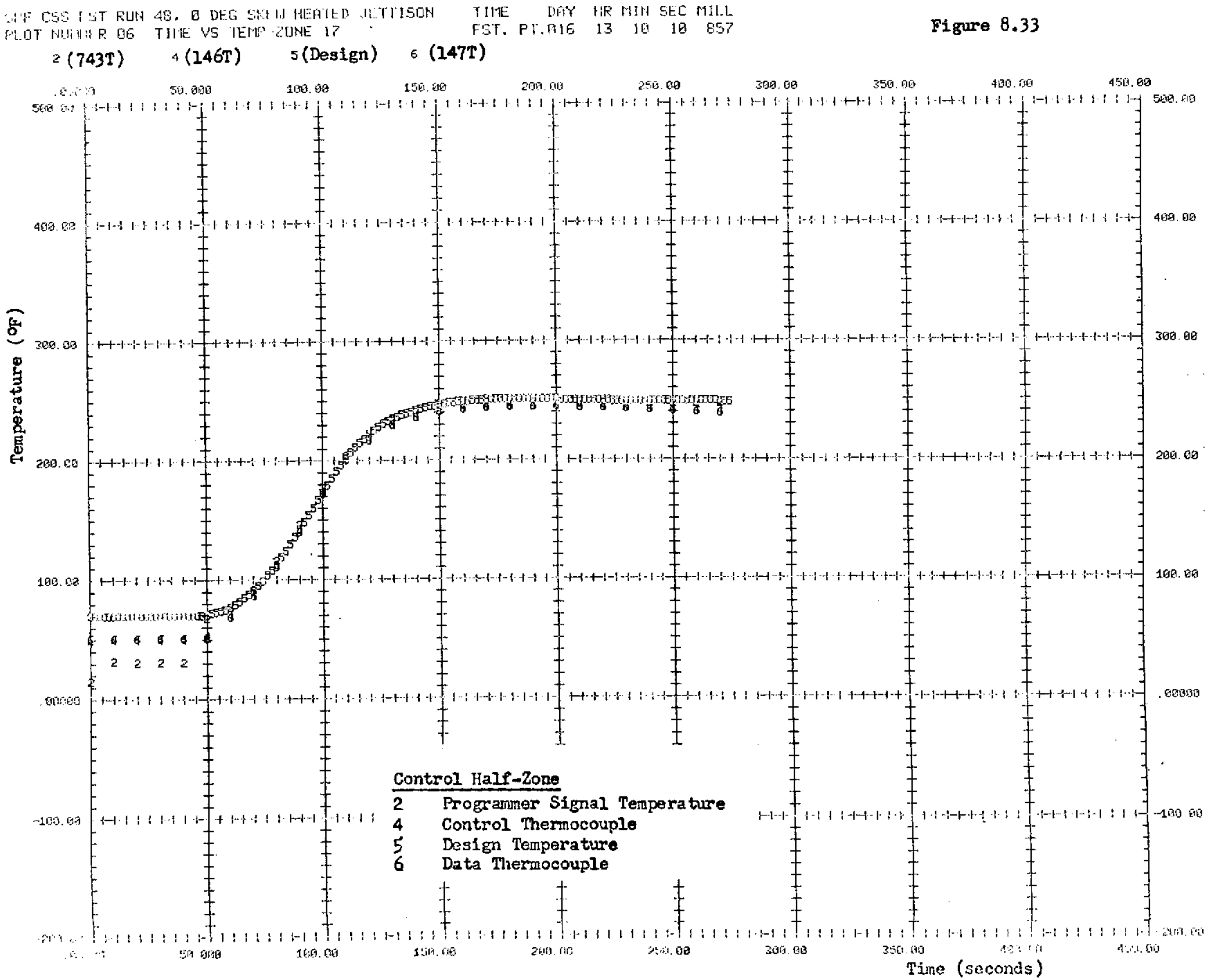
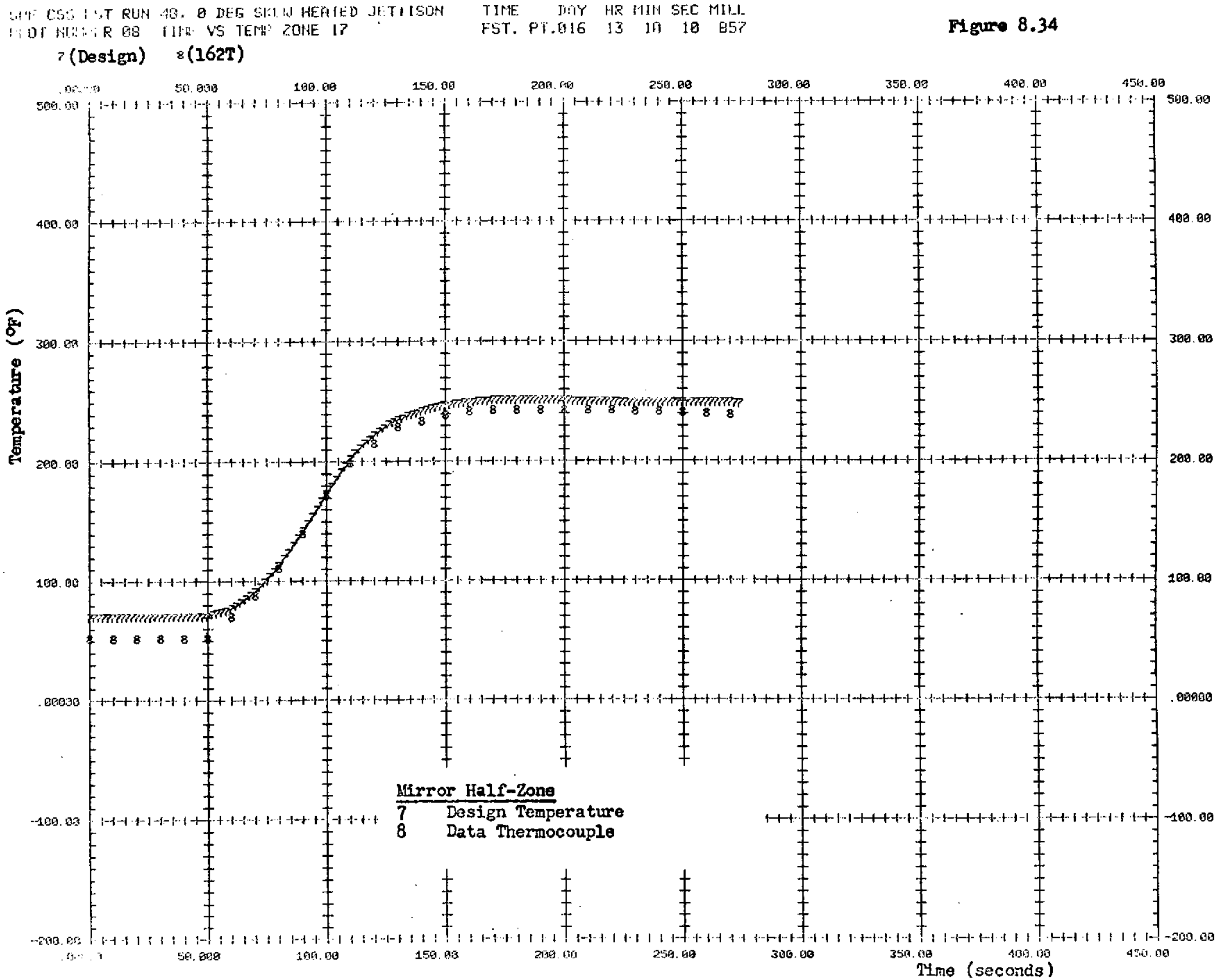


Figure 8.33



SRF CSS TST RUN 48, 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 06 TIME VS TEMP-ZONE 17
TIME DAY HR MIN SEC MILL
TST. PT.016 13 10 10 857
2 (743T)
4 (146T)
5 (Design)
6 (147T)
Temperature (°F)
Time (seconds)
Control Half-Zone
2 Programmer Signal Temperature
4 Control Thermocouple
5 Design Temperature
6 Data Thermocouple

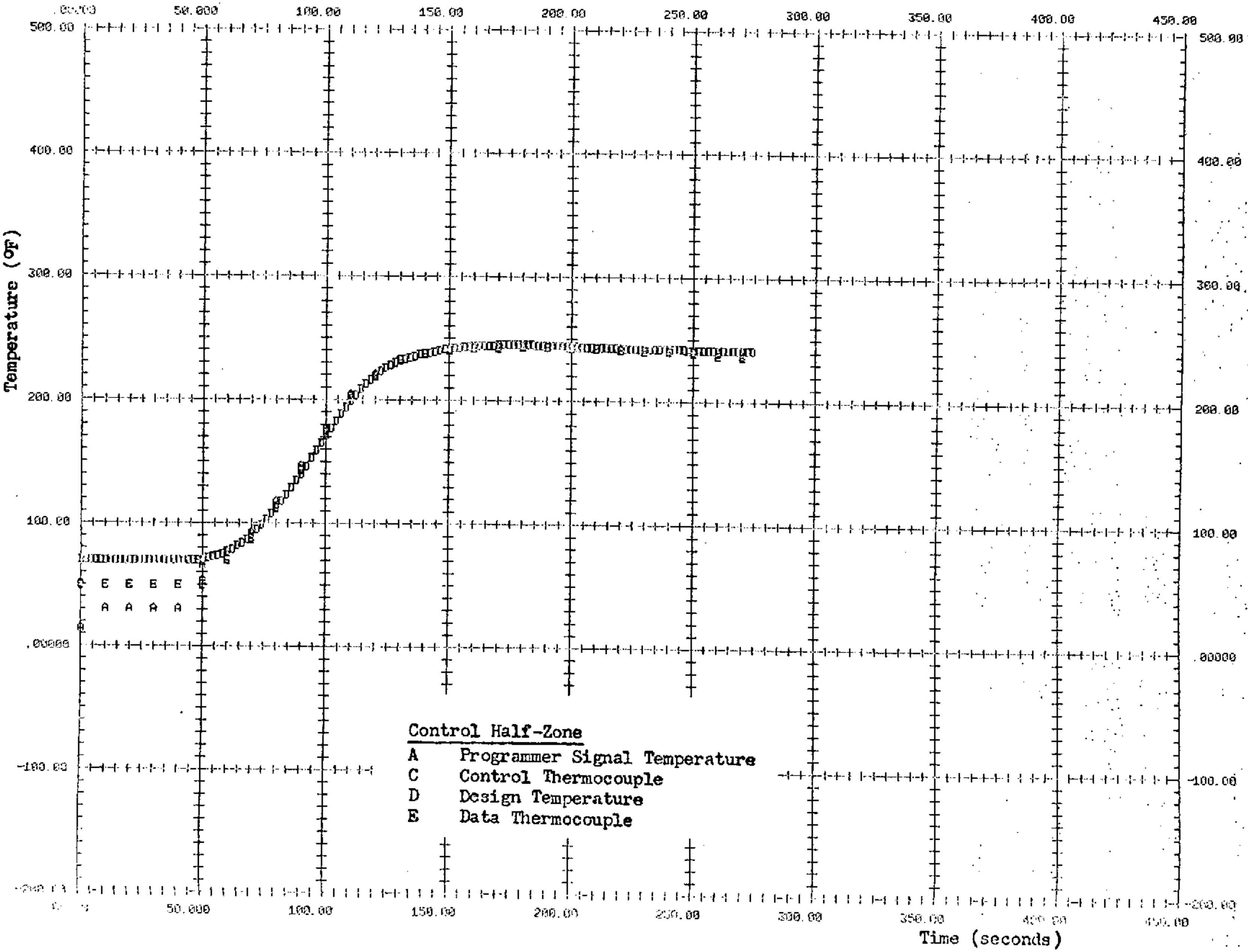
Figure 8.34


GMF CSG FST RUN 40, 0 DEG SKEW HEATED JETTISON
PLOT NUMBER 08 TIME VS TEMP ZONE 17
TIME DAY HR MIN SEC MILL
FST. PT.016 13 10 10 857
7 (Design) 8 (162T)
Temperature (°F)
Time (seconds)
Mirror Half-Zone
7 Design Temperature
8 Data Thermocouple

SMF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 14 TIME VS TEMP-ZONE 18 FST. PT.016 13 10 10 857

Figure 8.35

A (744T) C (151T) D (Design) E (152T)



SPF USS TST RUN 48, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 16 TIME VS TEMP ZONE 18   FST. PT.016 13 10 10 857

Figure 8.36

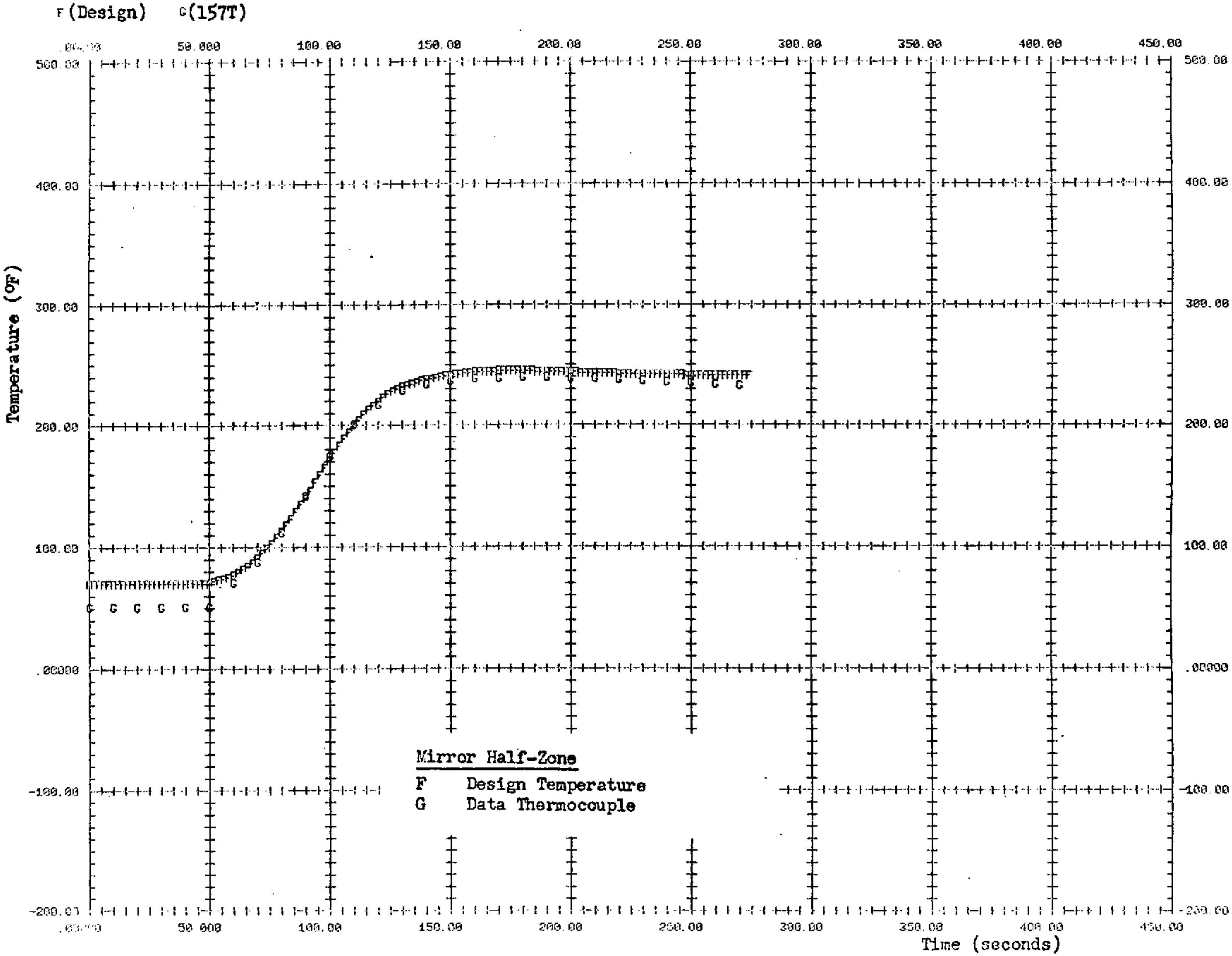
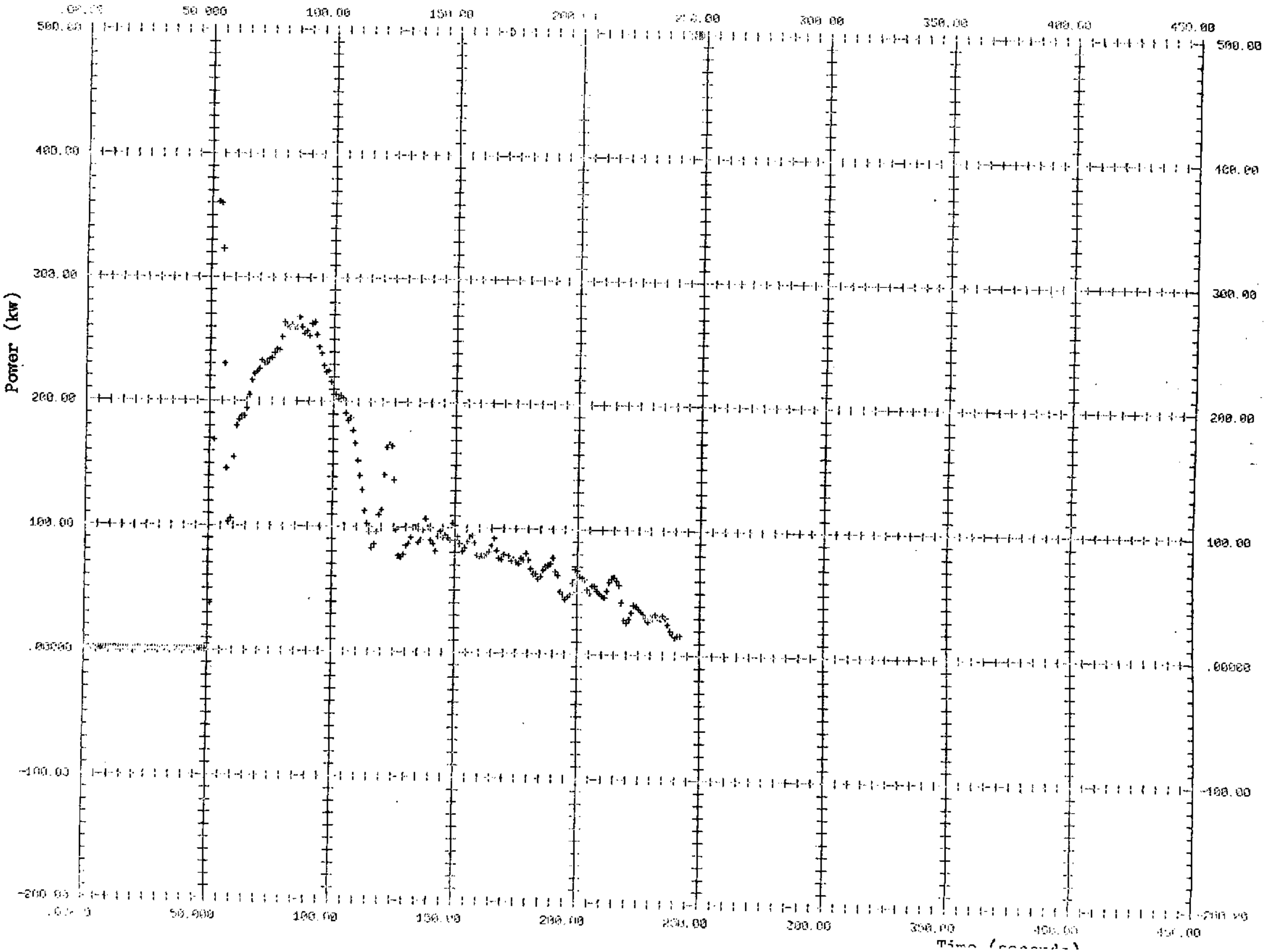


Figure 9.

Power history for heating zone no. 1 power controller.

SMF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 01   TIME VS POWER ZONE 01 (S.N.706)   FST. PT.016   13   10   10   857
1

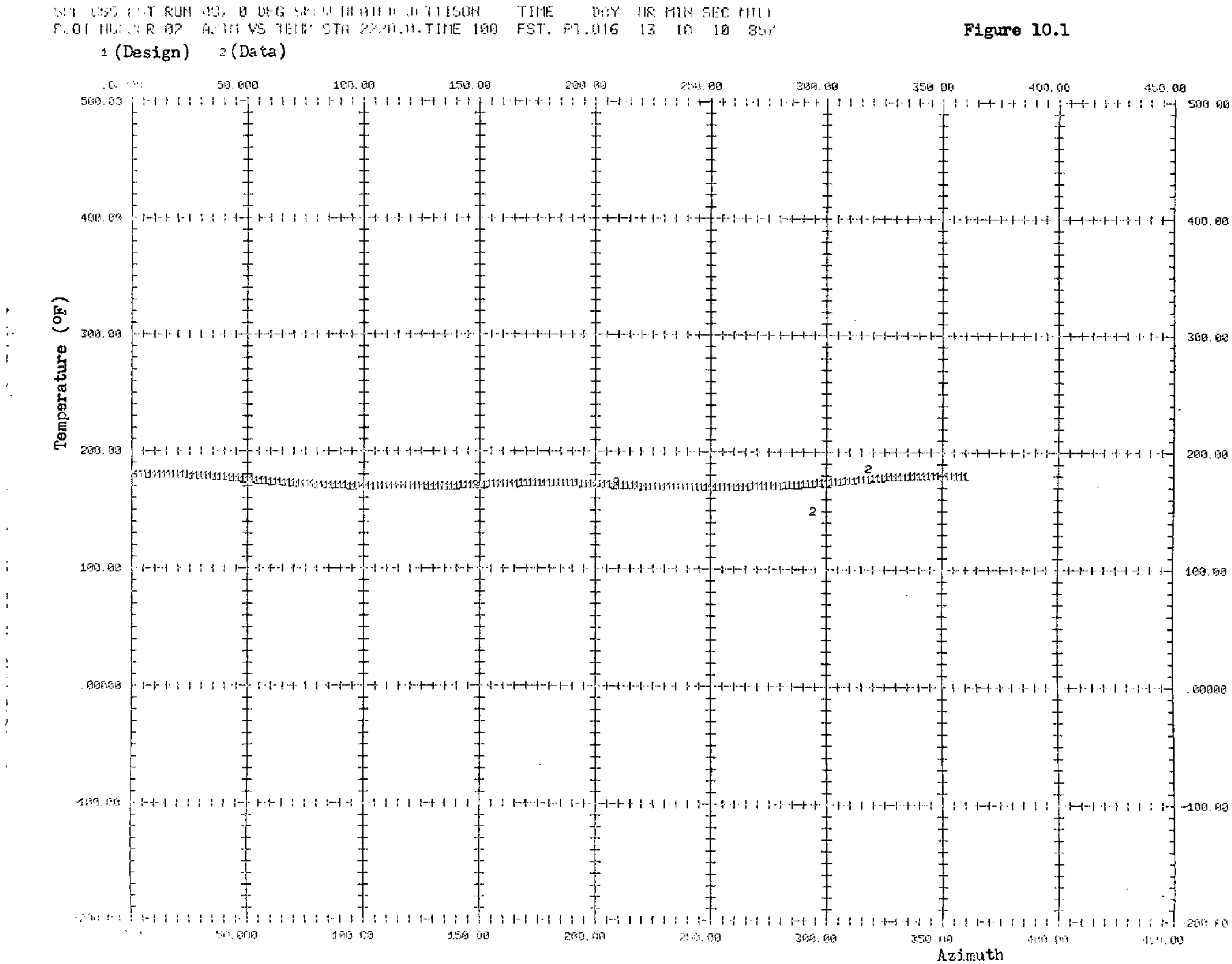
Figure 9



Figures 10.1 thru 10.40.

Design and data thermocouples circumferential temperature distributions.

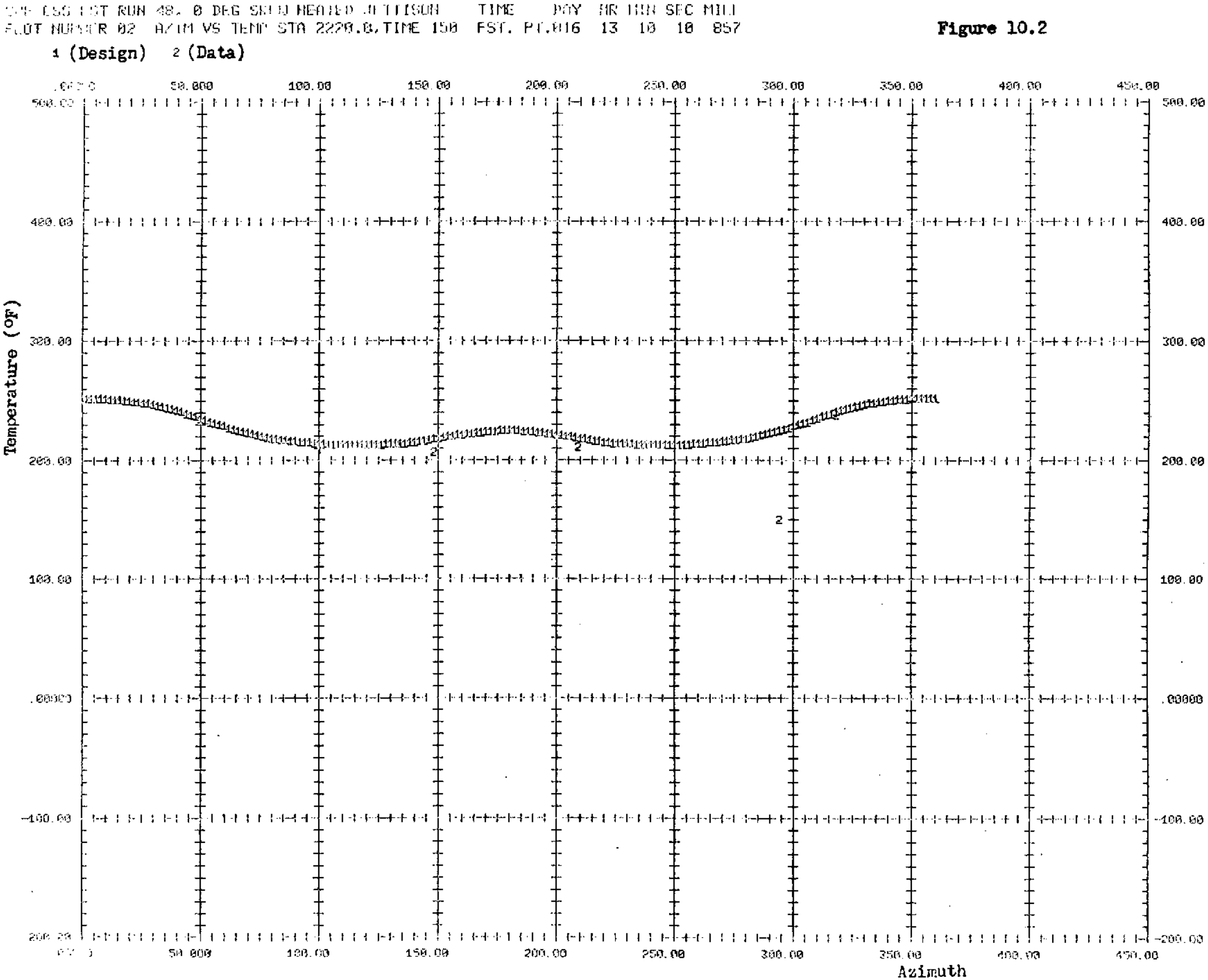
I



TIME DAY HR MIN SEC MILI
FST. PT.016 13 10 10 857
1 (Design) 2 (Data)
Temperature (°F)
Azimuth

Figure 10.1

Figure 10.2



PLOT NUMBER 02 AZIM VS TEMP STA 2220.0, TIME 150 FST. PT.016 13 10 10 857
TIME DAY HR MIN SEC MILL
1 (Design) 2 (Data)
Temperature (°F)
Azimuth
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

SPF CSS EST RUN 40. 0 DEG SW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 02 AZIM VS TEMP STA 2220.0, TIME 200 FST. PT.016 13 10 10 857

Figure 10.3

1 (Design) 2 (Data)

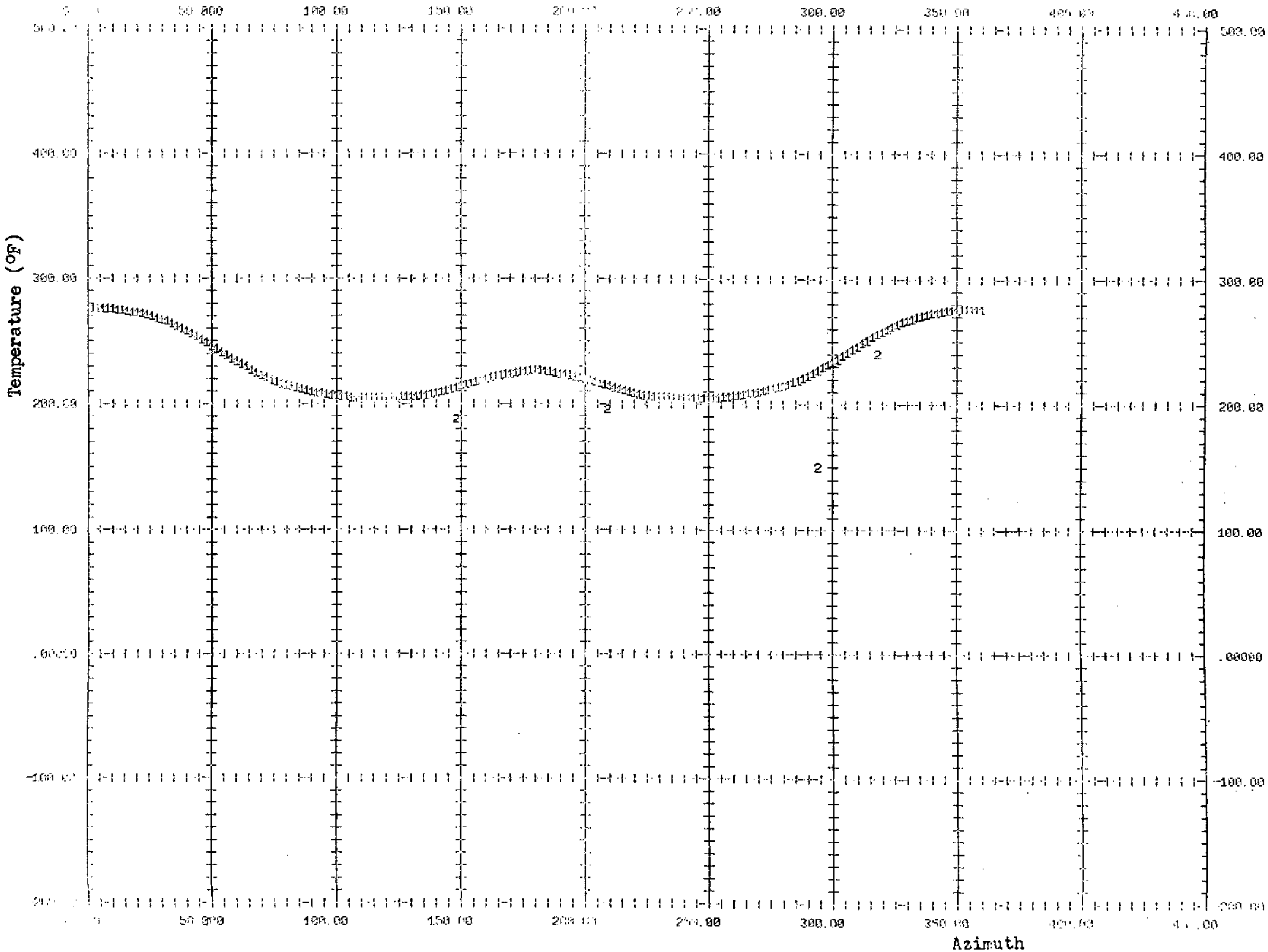


Figure 10.4

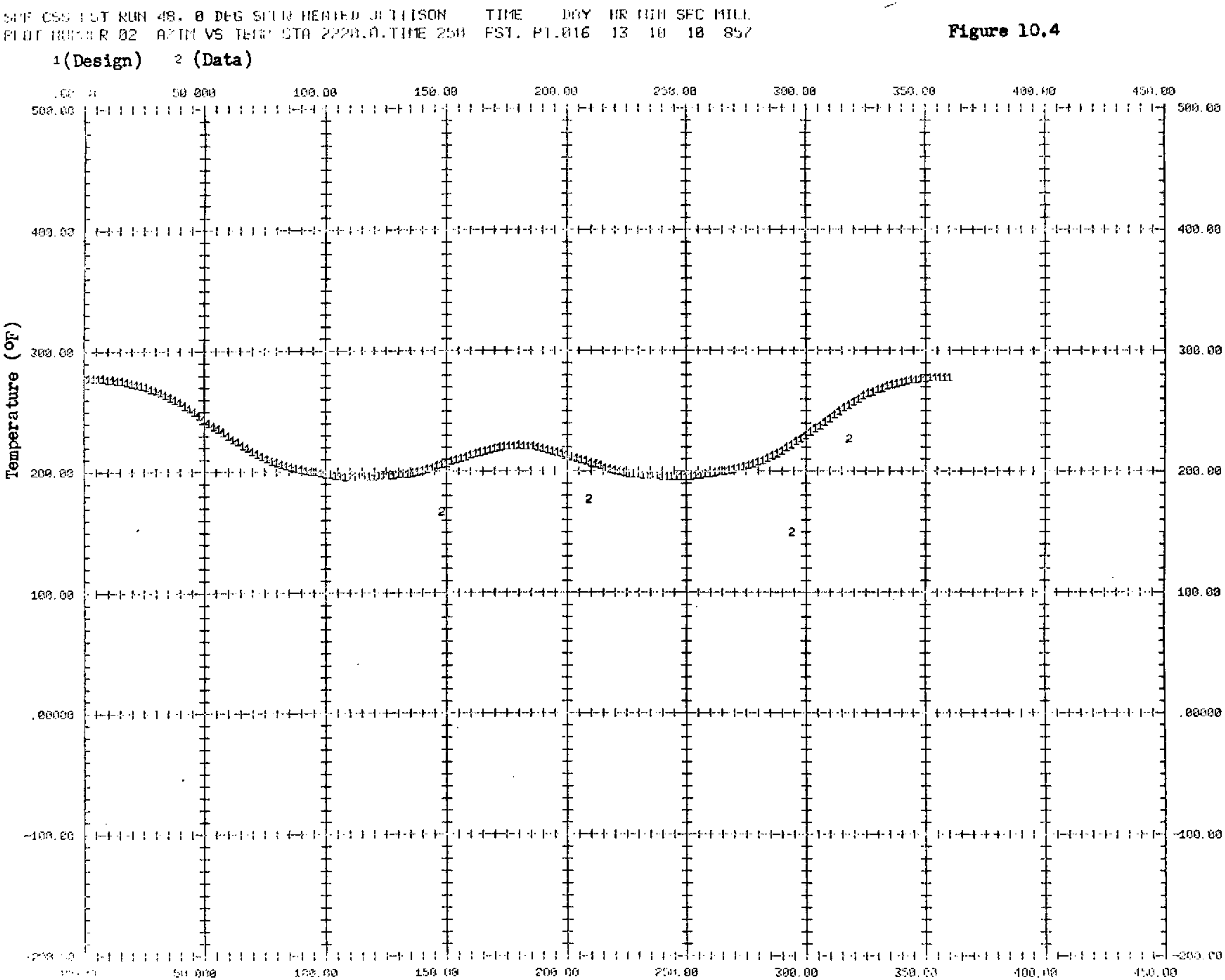
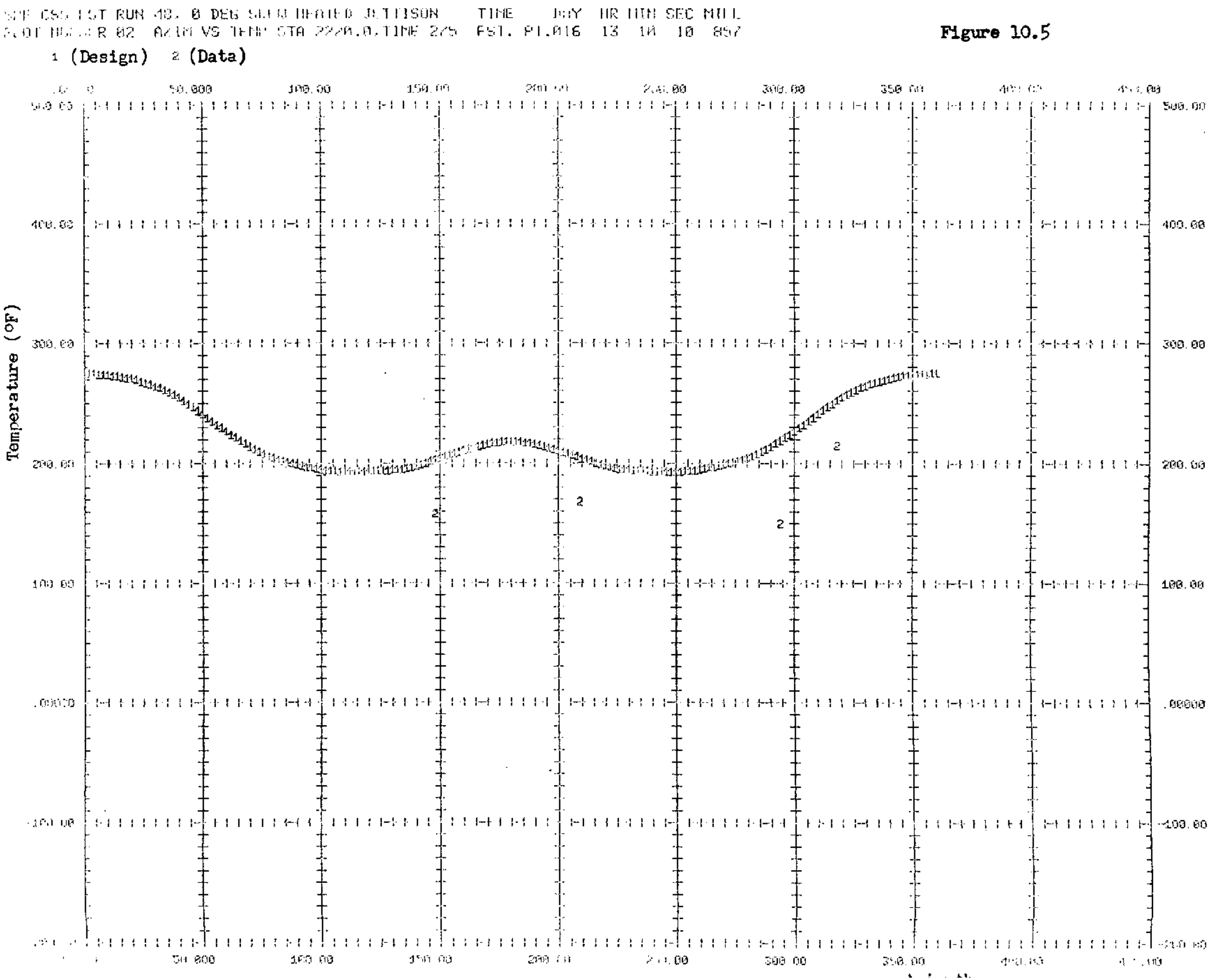

SMF CSS TST RUN 48. 0 DEG SPIN HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 02 AZIM VS TEMP STA 2220.0.TIME 250 FST. PT.016 13 10 10 857
1 (Design) 2 (Data)
Temperature (°F)
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00

Figure 10.5



TIME DAY HR MIN SEC MILL
13 10 10 857
1 (Design) 2 (Data)
Temperature (°F)
50.000
100.00
150.00
200.00
300.00
350.00
500.00
400.00
300.00
200.00
100.00
.00000
-100.00

SPF CSS TST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS TEMP STA 2250.0,TIME 100 FST. PT.016 13 10 10 857

Figure 10.6

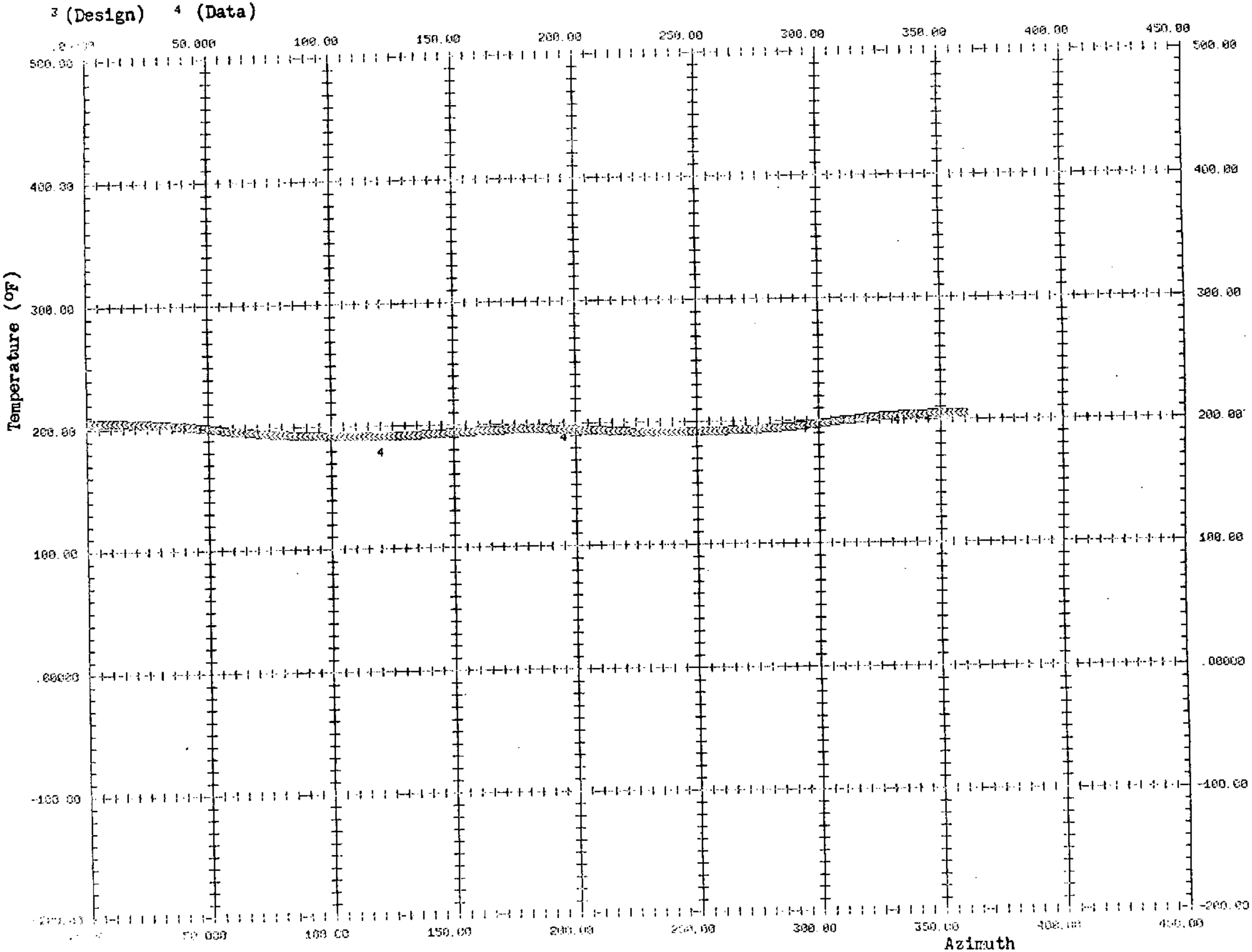


Figure 10.7

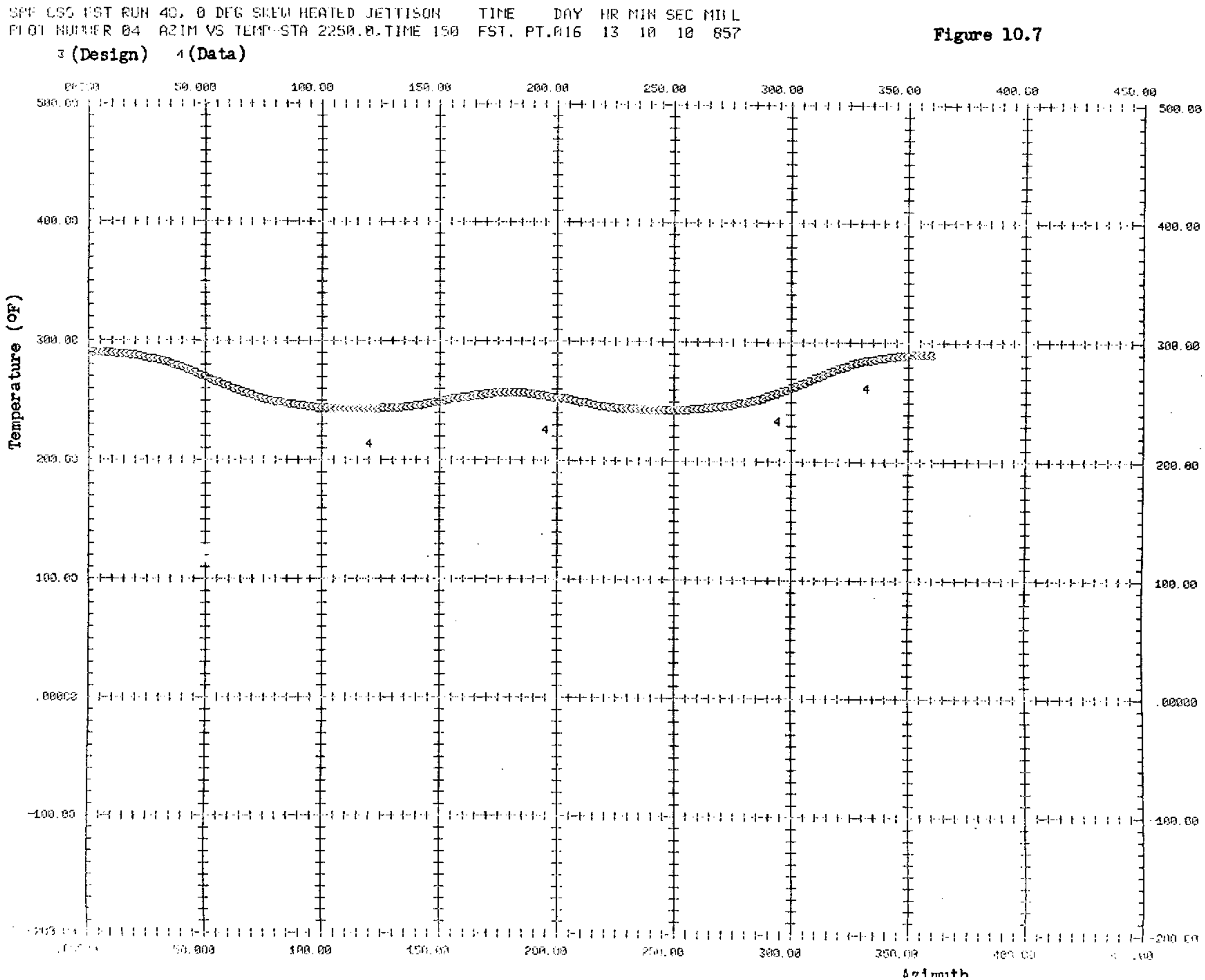
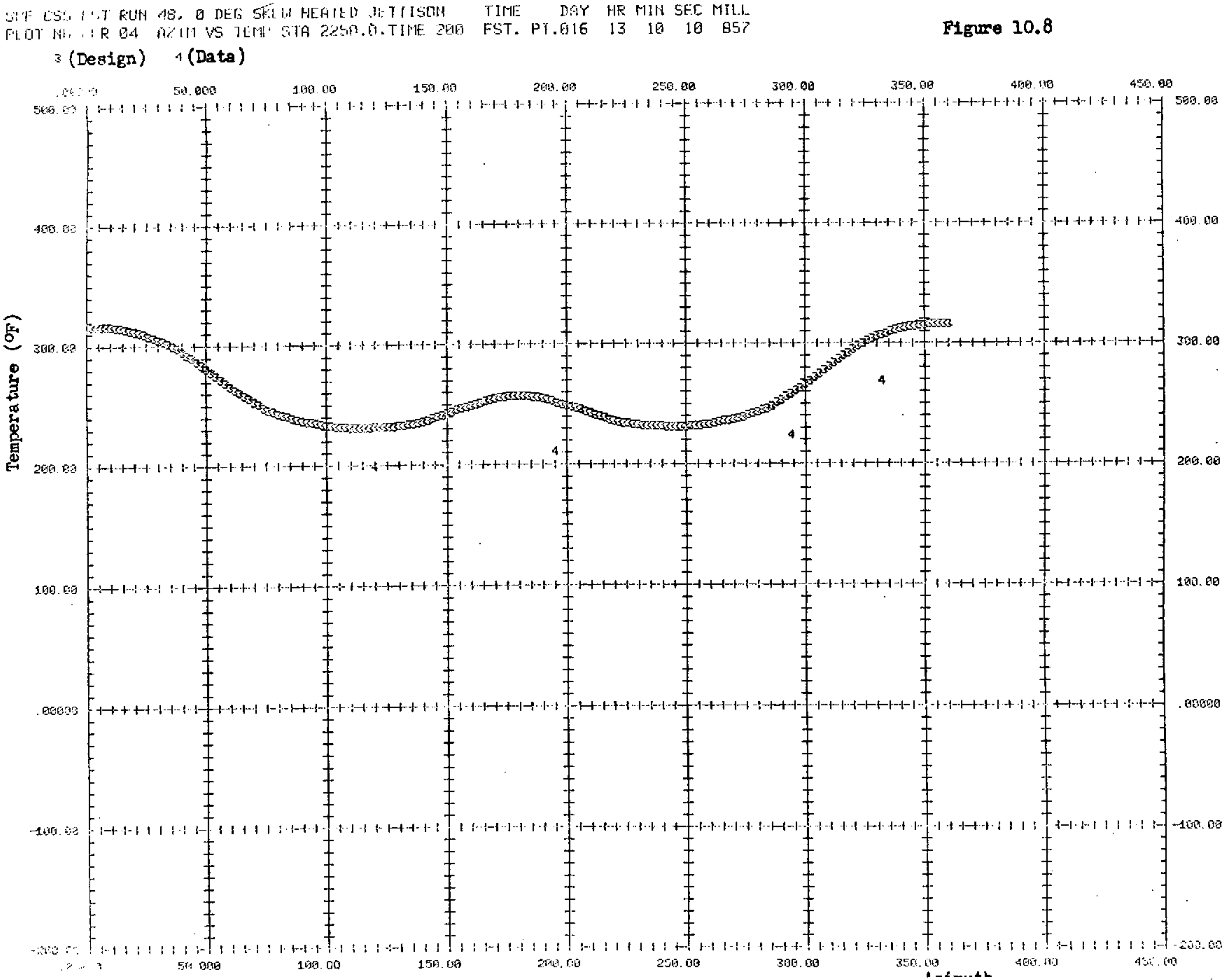

SPF CSS FST RUN 40, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS TEMP-STA 2250.0.TIME 150 FST. PT.016 13 10 10 857
3 (Design) 4 (Data)
Temperature (OF)
Azimuth
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00

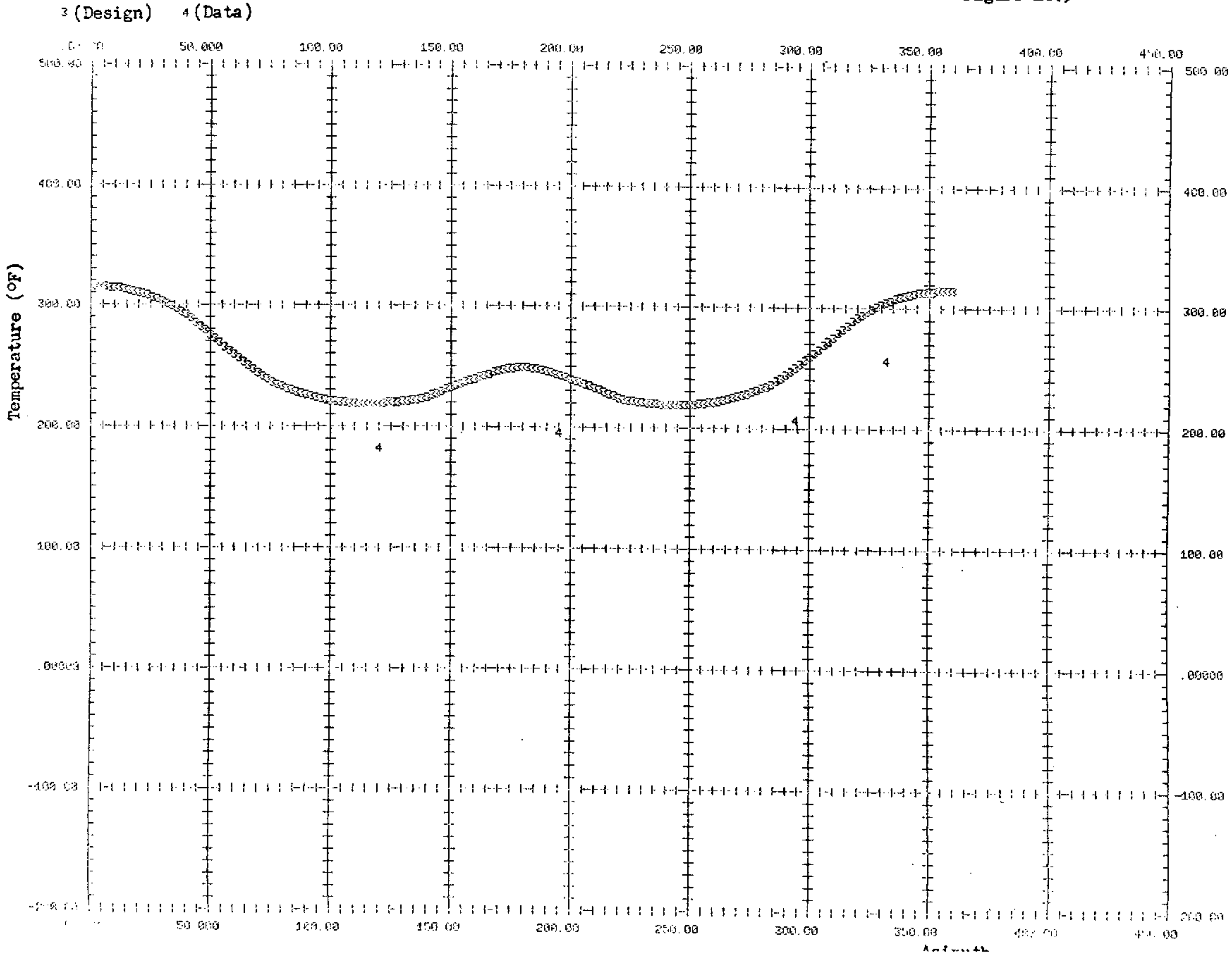
Figure 10.8



SMF CSS FST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS TEMP STA 2250.0.TIME 200 FST. PT.016 13 10 10 857
3 (Design) 4 (Data)
Temperature (°F)
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00
4

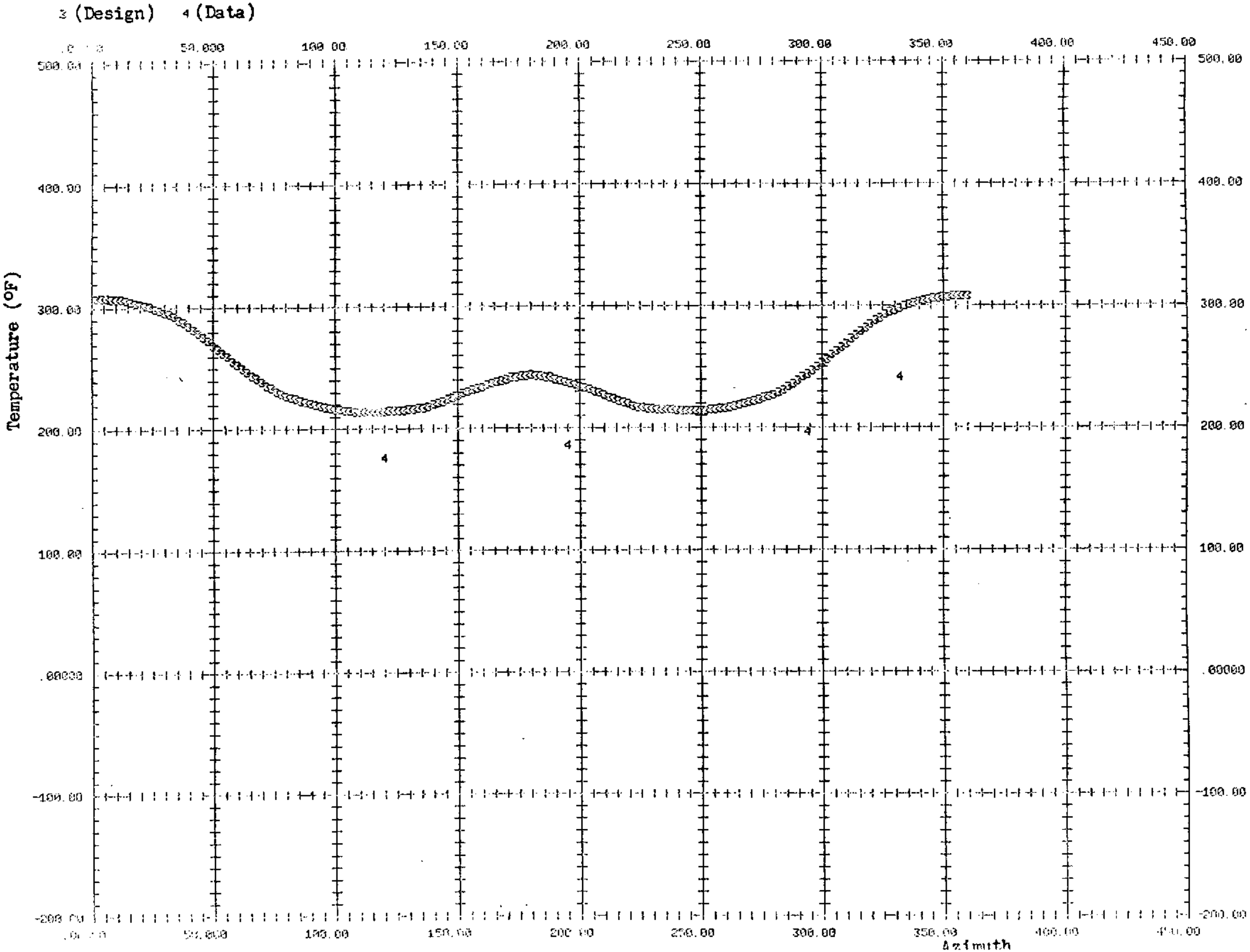
SMP CSS IST RUN 48, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS TEMP STA 2250.0:TIME 250 FST. PT.016 13 10 10 857

Figure 10.9



SRM DSS FNT RUN 43. 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS TEMP STA 2250.0,TIME 275 EST. P1.016 13 10 10 857

Figure 10.10



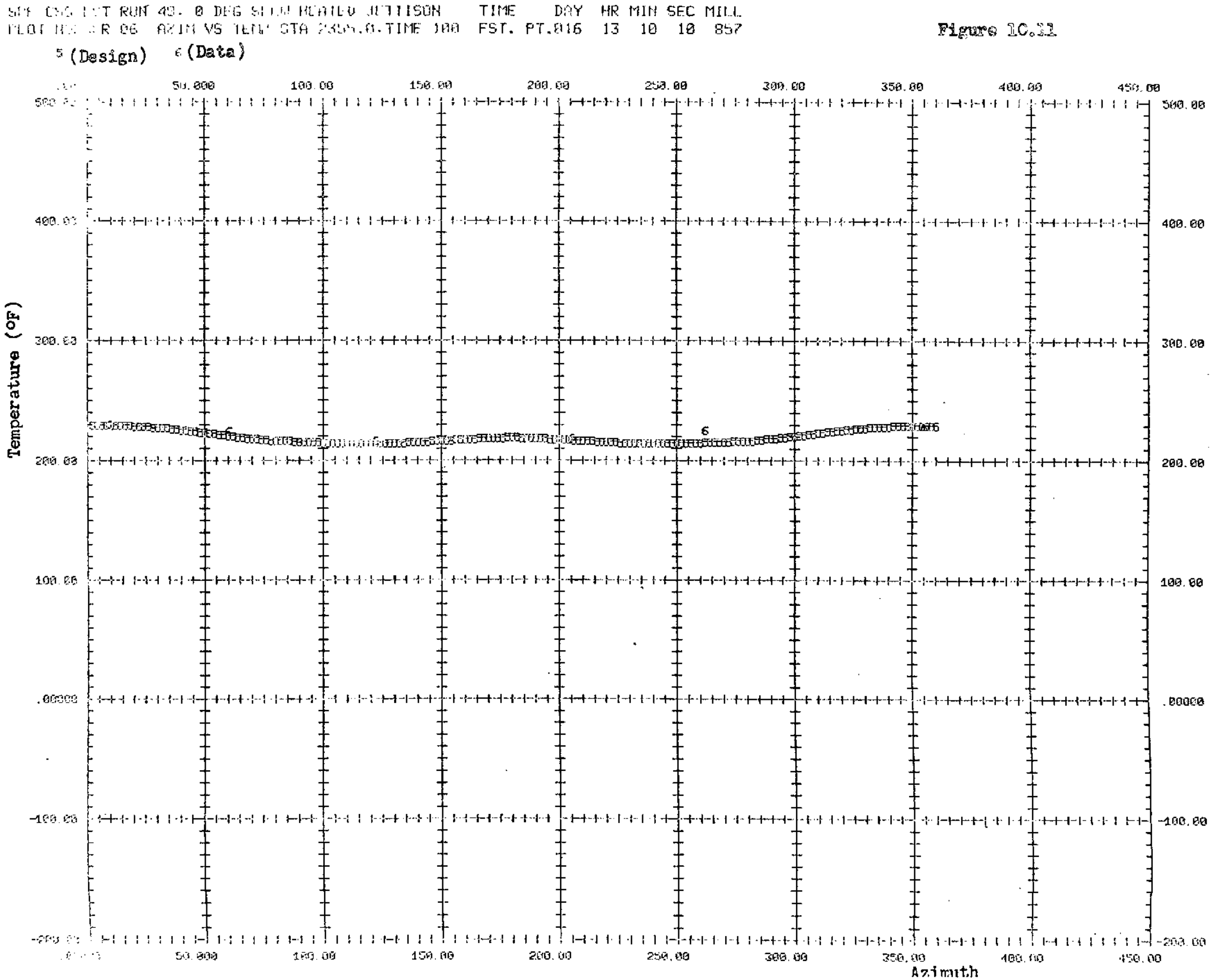
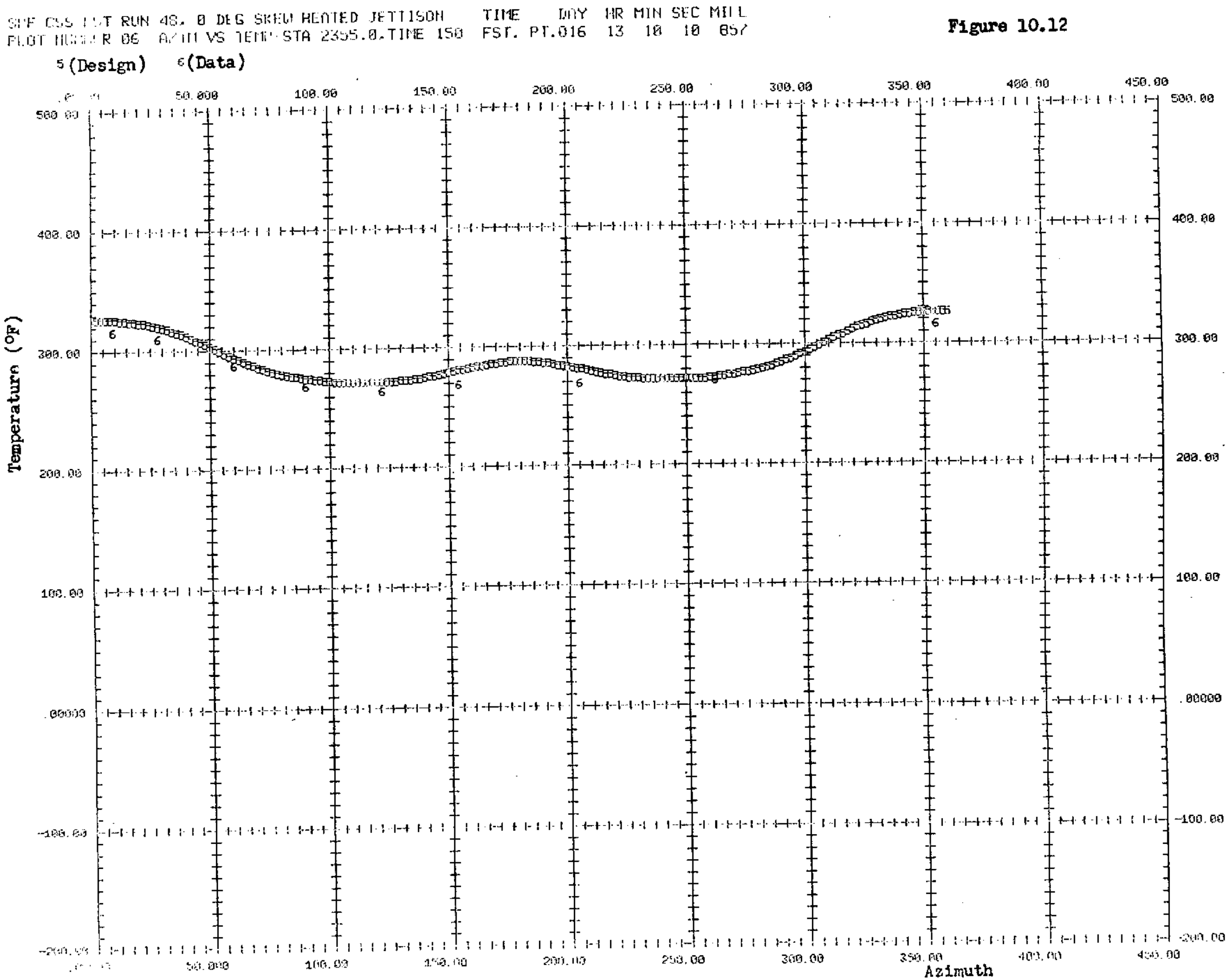


Figure 10.21

Figure 10.12



SRF CSS FVT RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 AZIM VS TEMP STA 2355.0.TIME 150 FST. PT.016 13 10 10 857
5 (Design) 6 (Data)
Temperature (°F)
Azimuth

SMP CSS FST RUN 49, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NO. TR 06 AZIN VS TEMP STA 2355.0 TIME 200 FST. P1.016 13 10 10 857

Figure 10.13

5 (Design) 6 (Data)

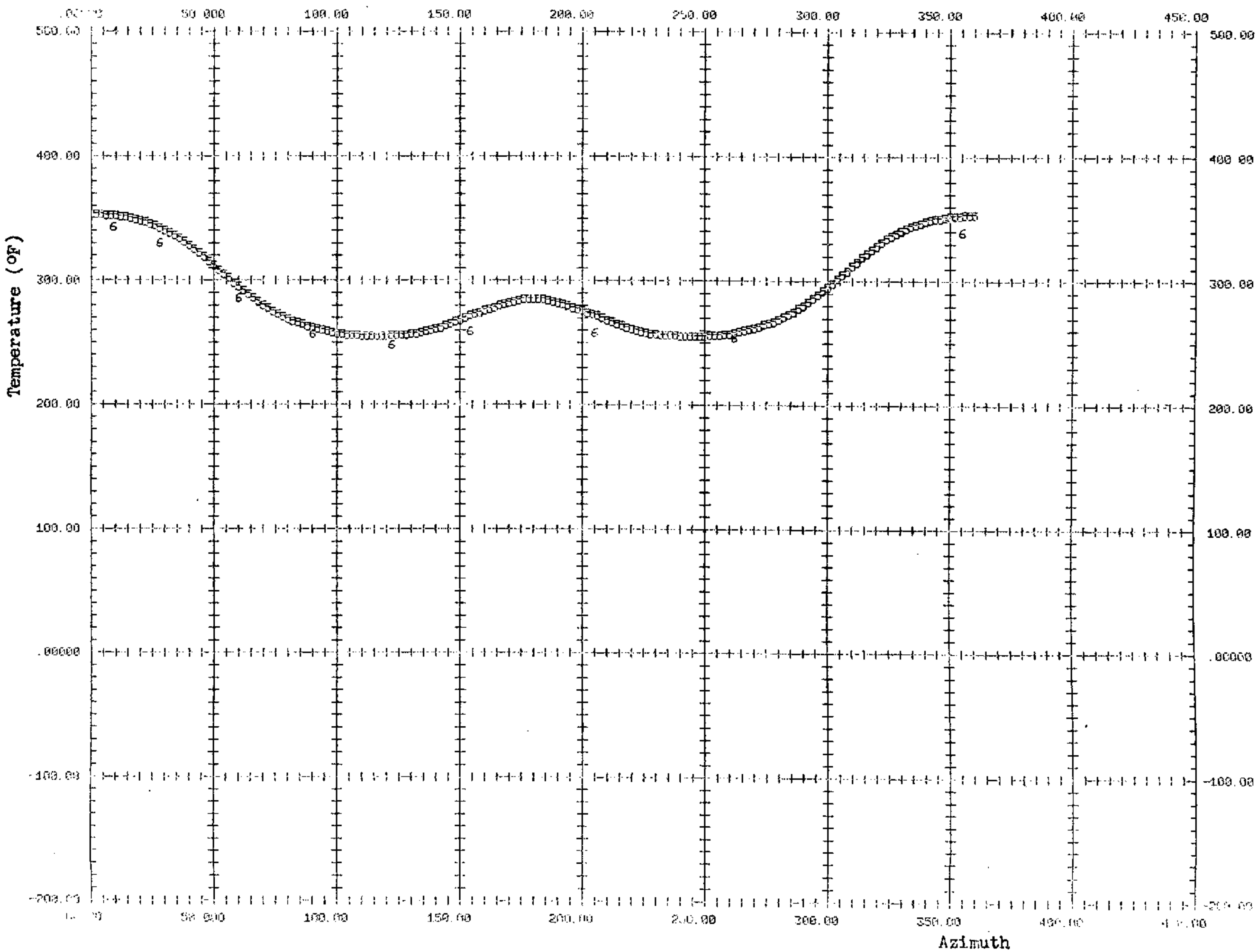
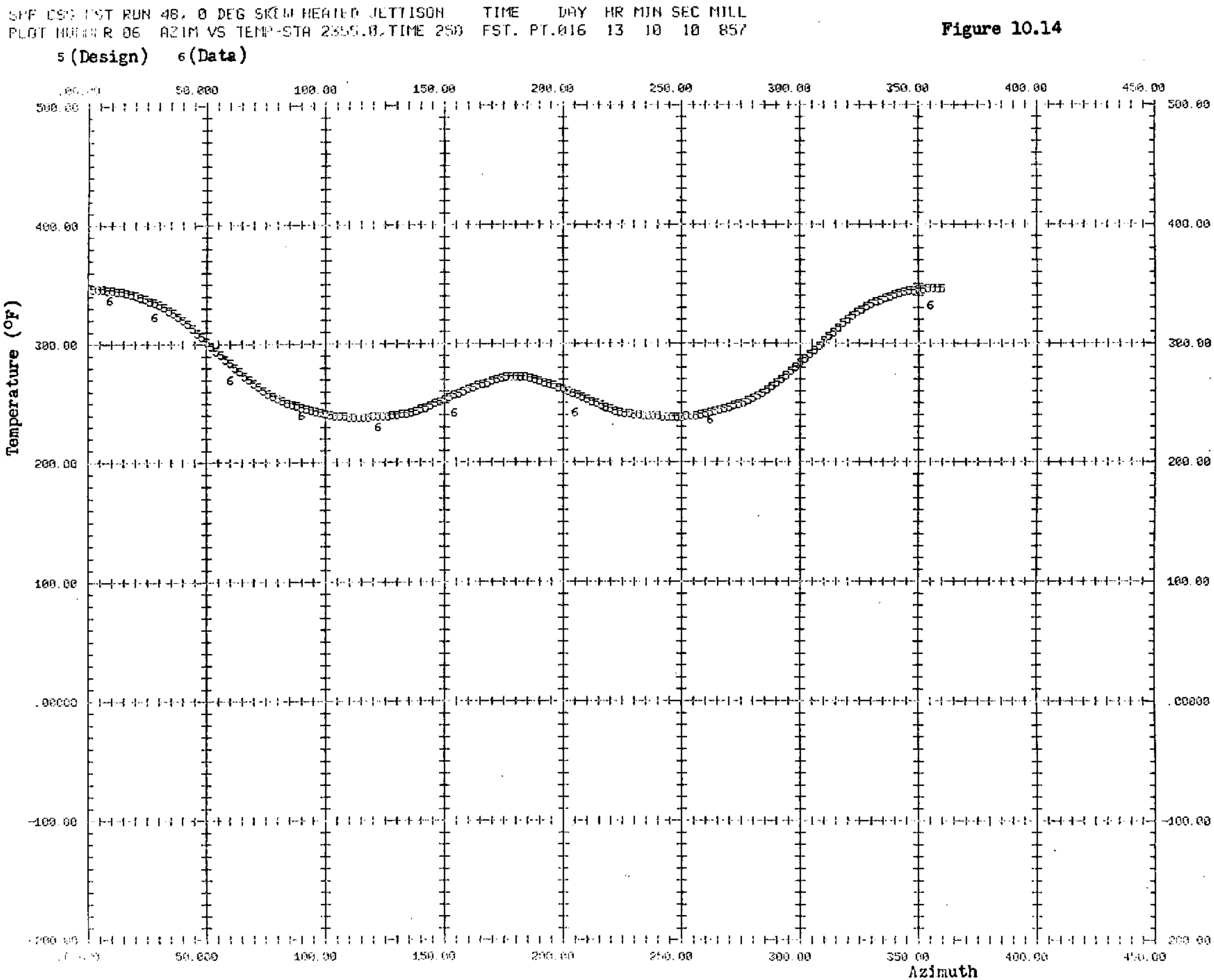
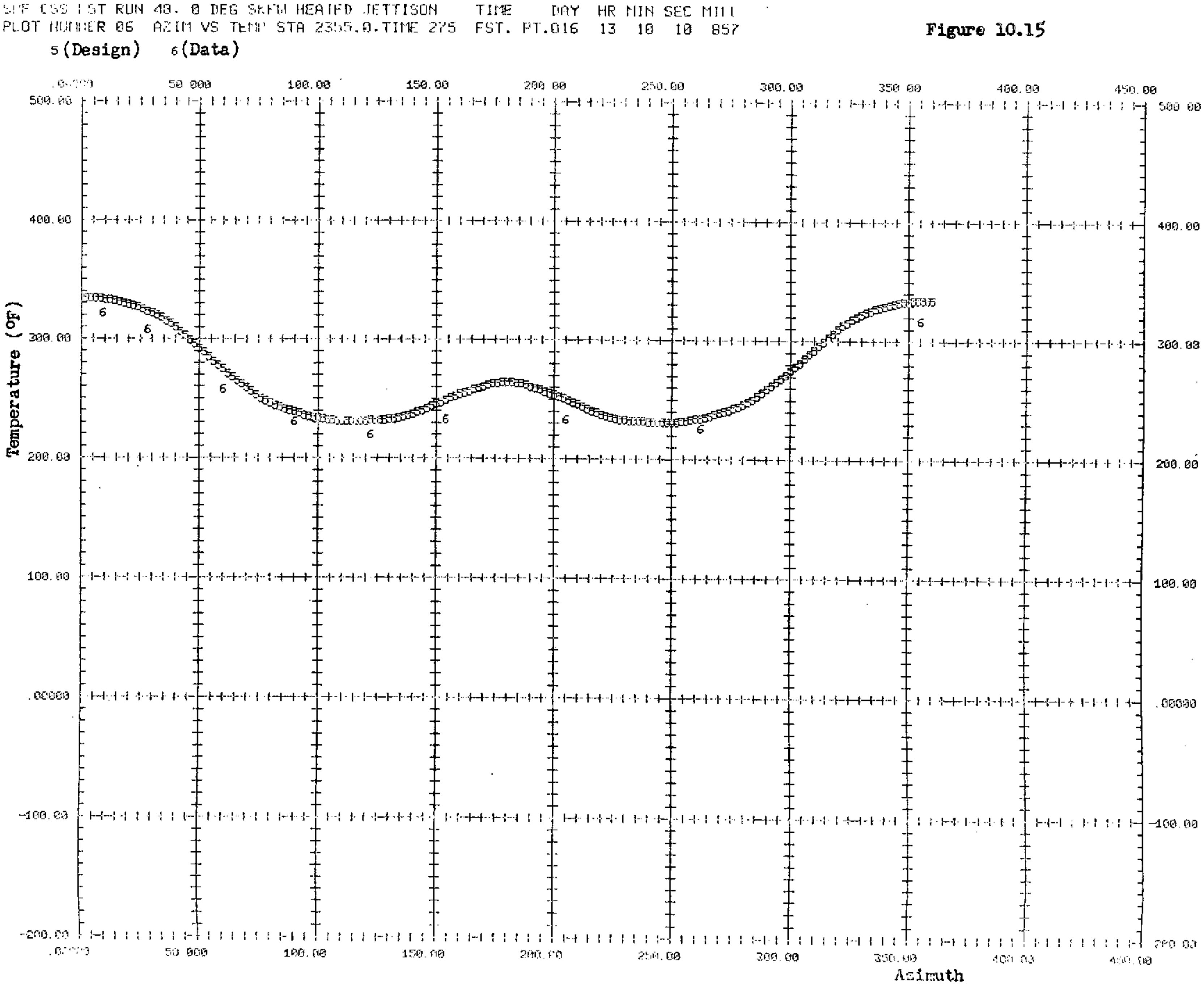


Figure 10.14



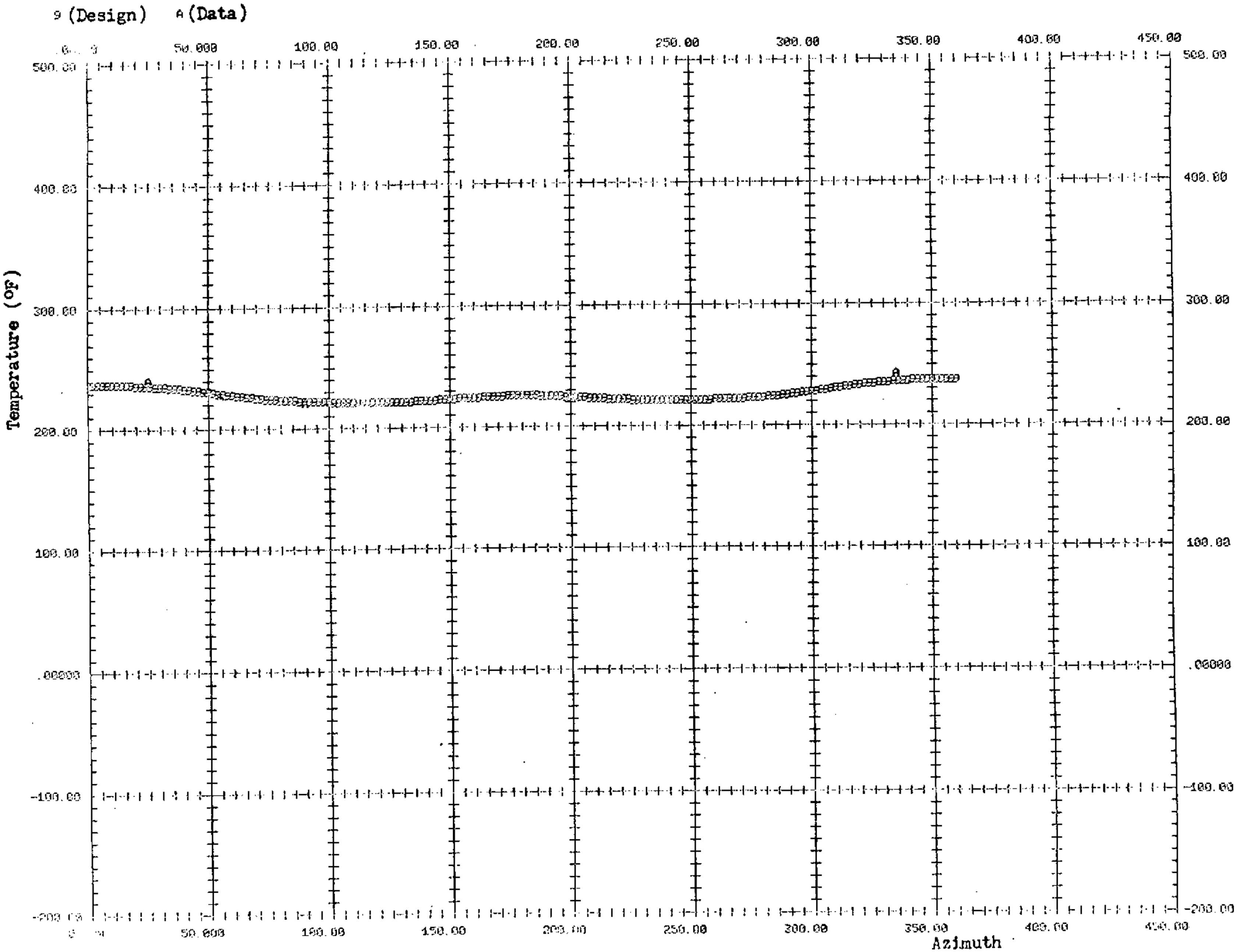
SRF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 AZIM VS TEMP-STA 2355.0,TIME 250 FST. PT.016 13 10 10 857
5 (Design) 6 (Data)
Temperature (°F)
Azimuth
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

Figure 10.15


SRF CSS FST RUN 40. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 AZIM VS TEMP STA 2355.0.TIME 275 FST. PT.016 13 10 10 857
5 (Design) 6 (Data)
Temperature (°F)
Azimuth
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

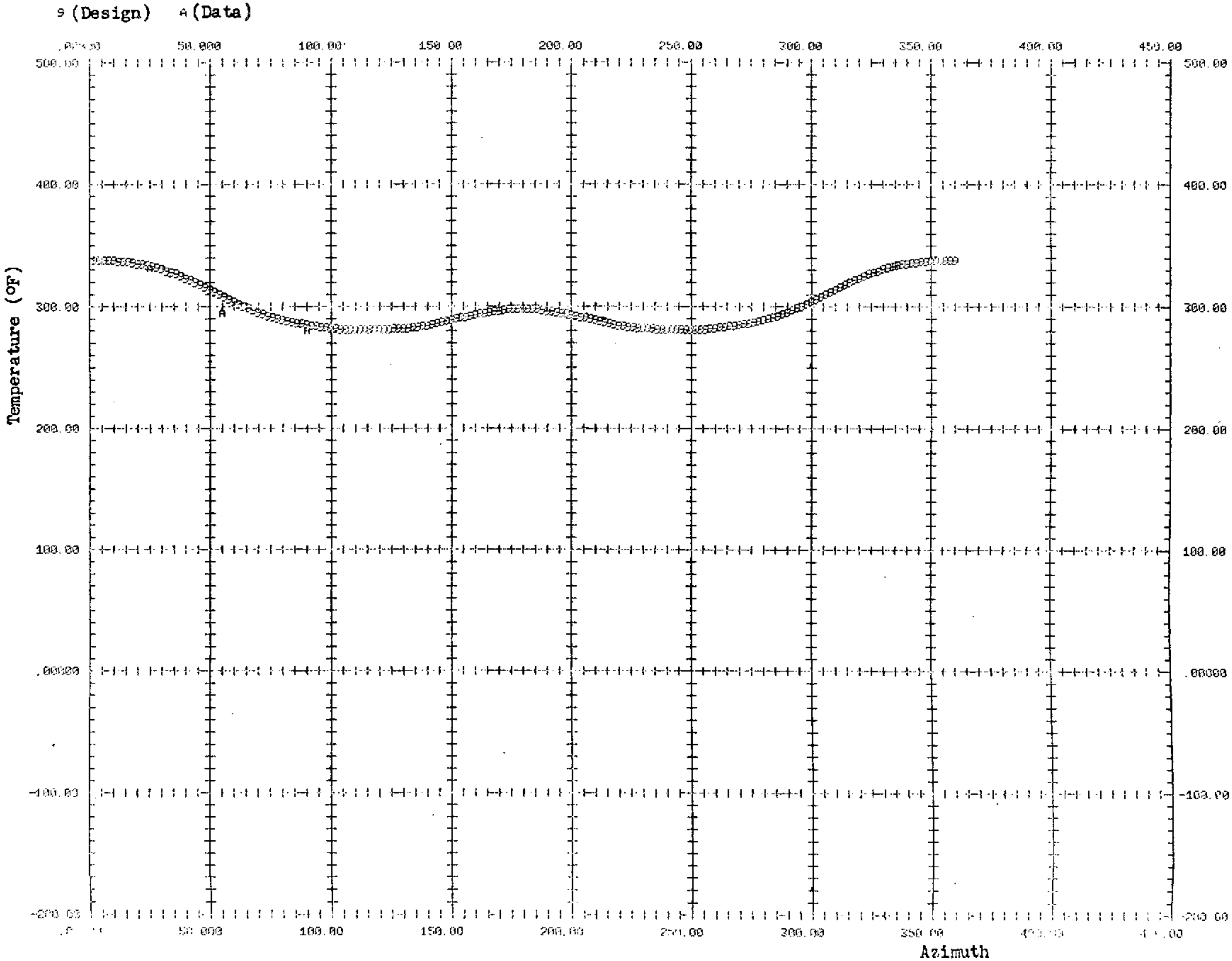
SRM CSS FST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 10 AZIM VS TEMP STA 2552.0,TIME 100 FST. PT.016 13 10 10 857

Figure 10.16



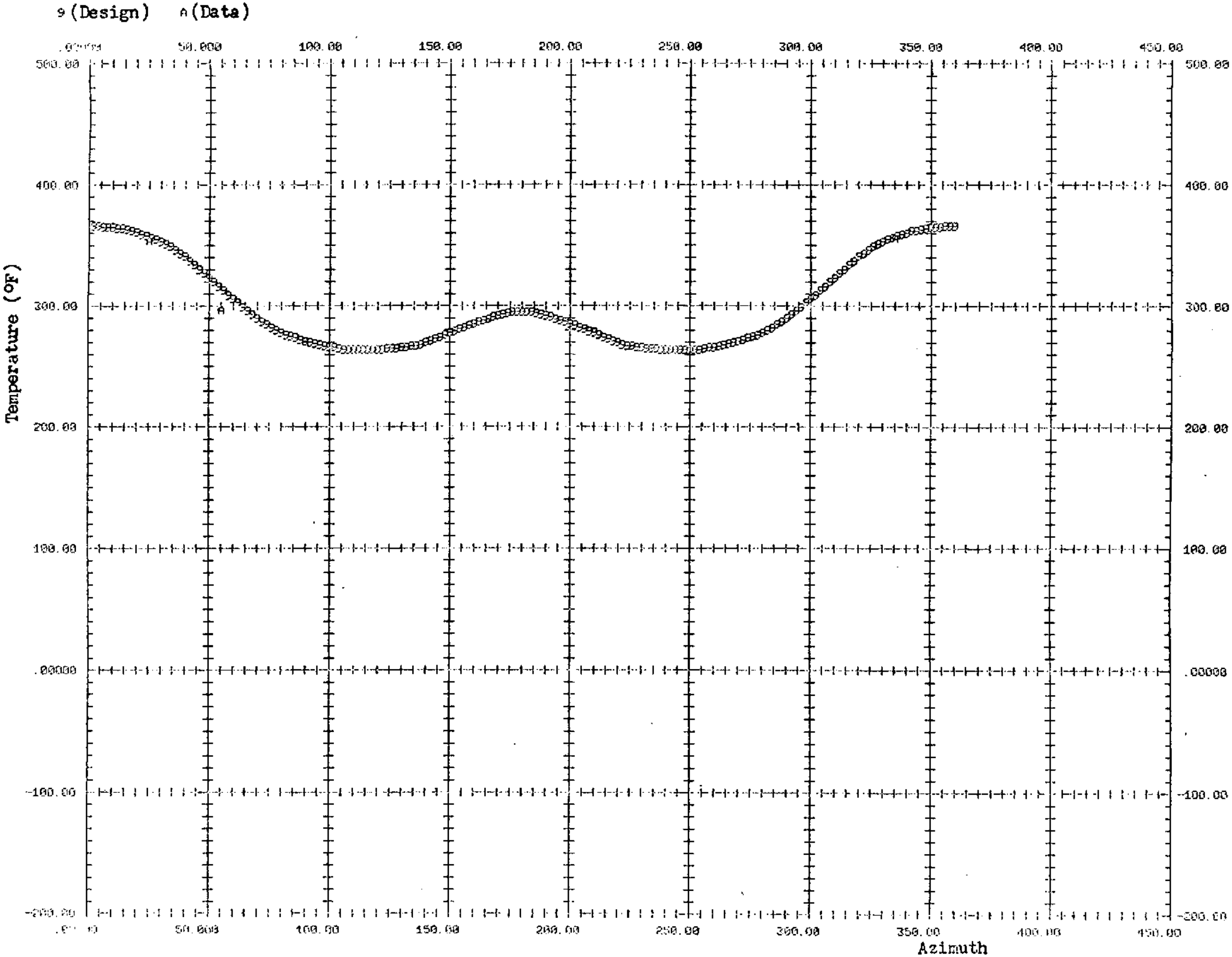
SMF CSS TST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 10 AZIM VS TEMP STA 2552.0.TIME 150 FST. PT.016 13 10 10 857

Figure 10.17



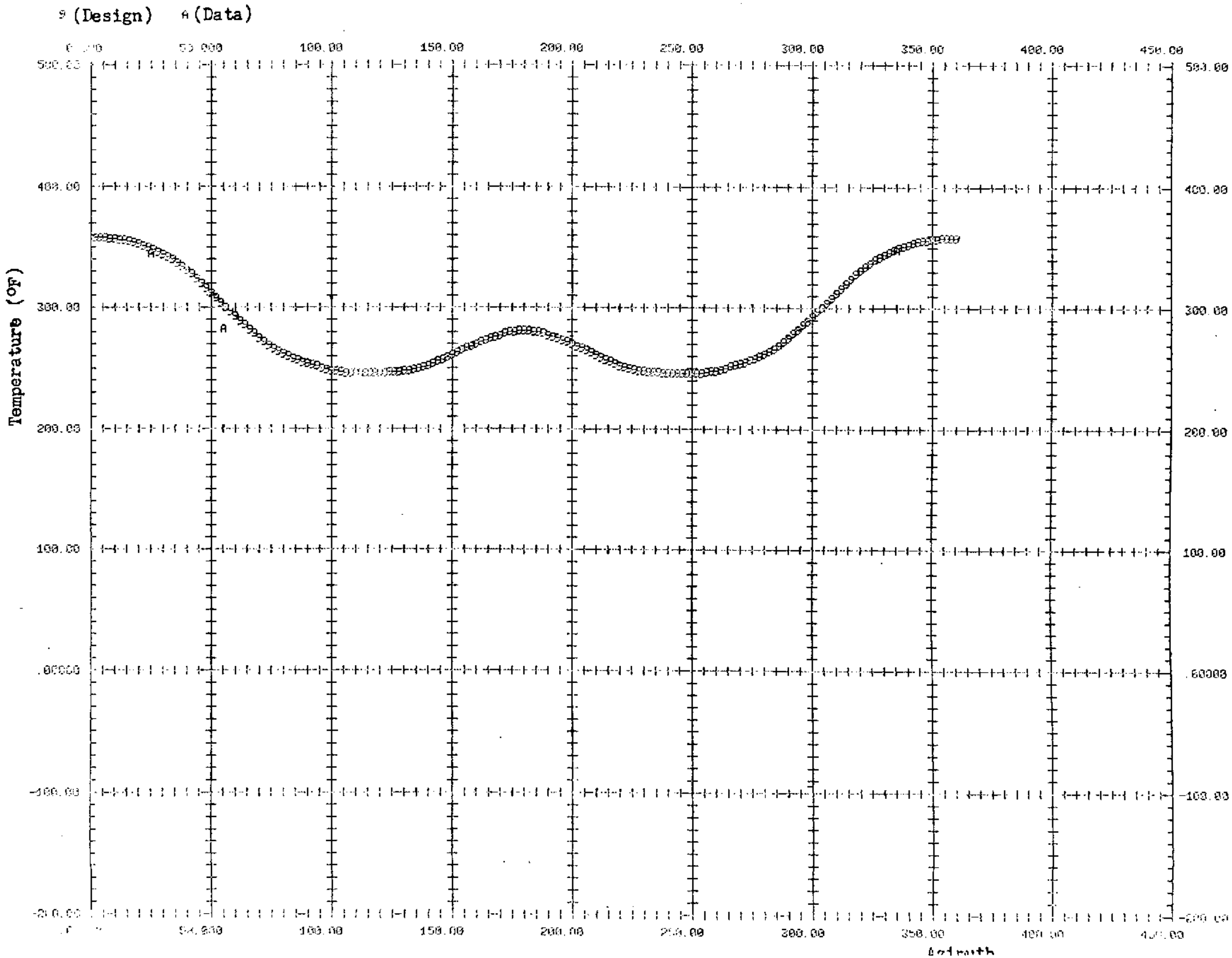
SMF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 10 AZIM VS TEMP STA 2552.0.TIME 200 FST. PT.016 13 10 10 857

Figure 10.18



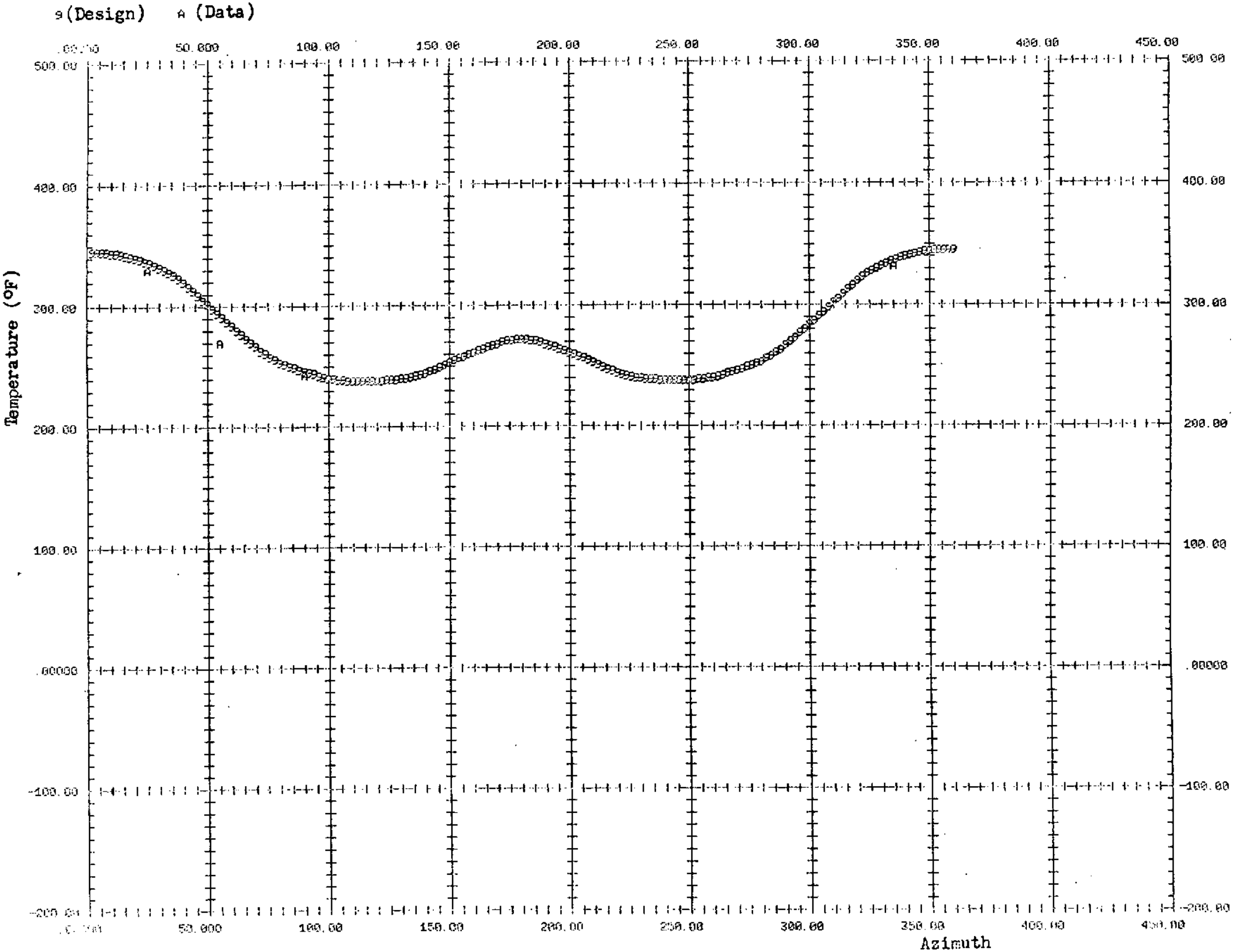
SMF CSS TST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 10 AZIM VS TEMP STA 2552.0 TIME 250 FST. PT.016 13 10 10 857

Figure 10.19



SPF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON TIME- DAY HR MIN SEC MILL
PLOT NUMBER 10 AZIM VS TEMP STA 2552.0.TIME 275 FST. PT.016 13 10 10 857

Figure 10.20



SMF CSS FST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS TEMP-STA 2626.5,TIME 100 FST. PT.016 13 10 10 857

Figure 10.21

B (Design) C (Data)

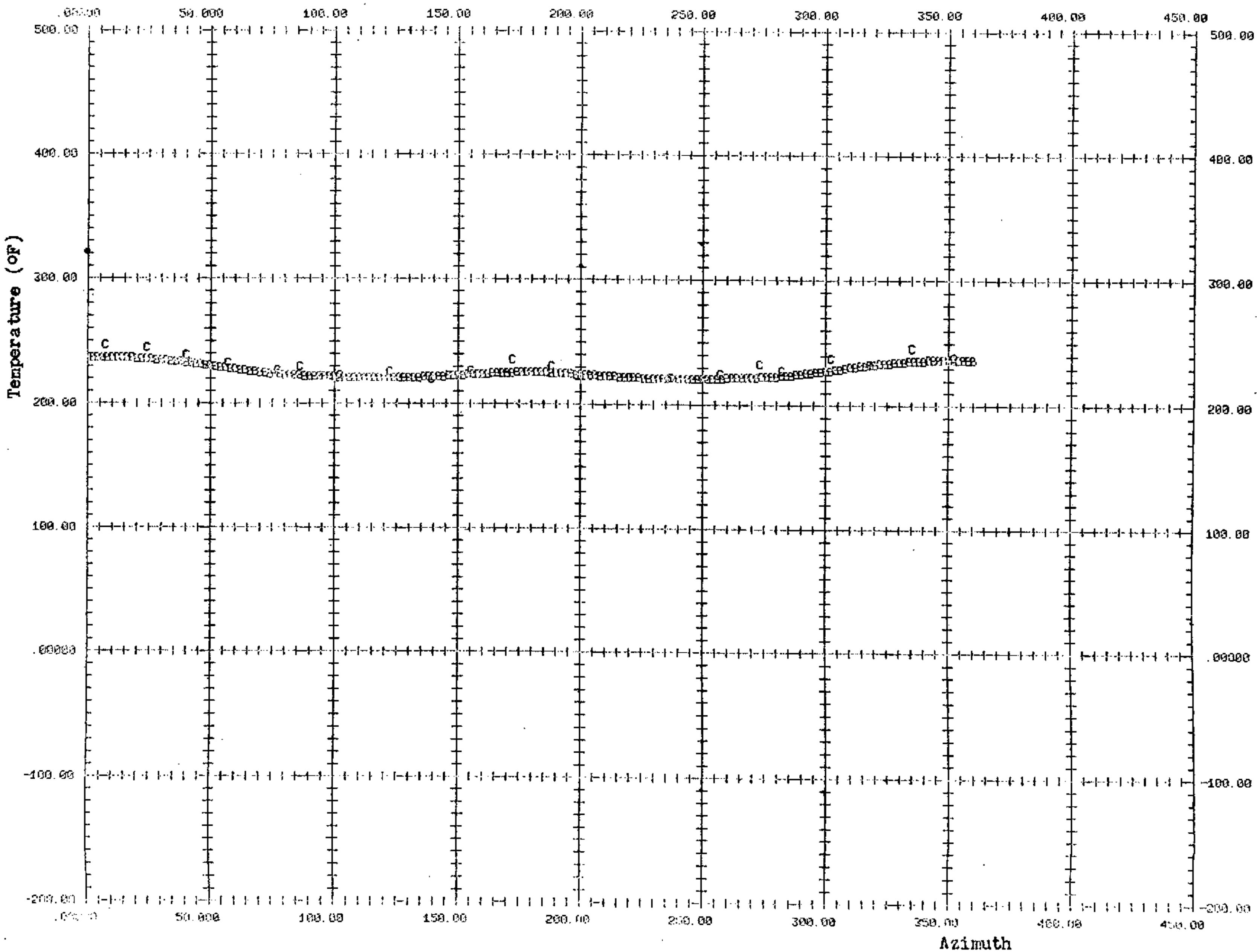
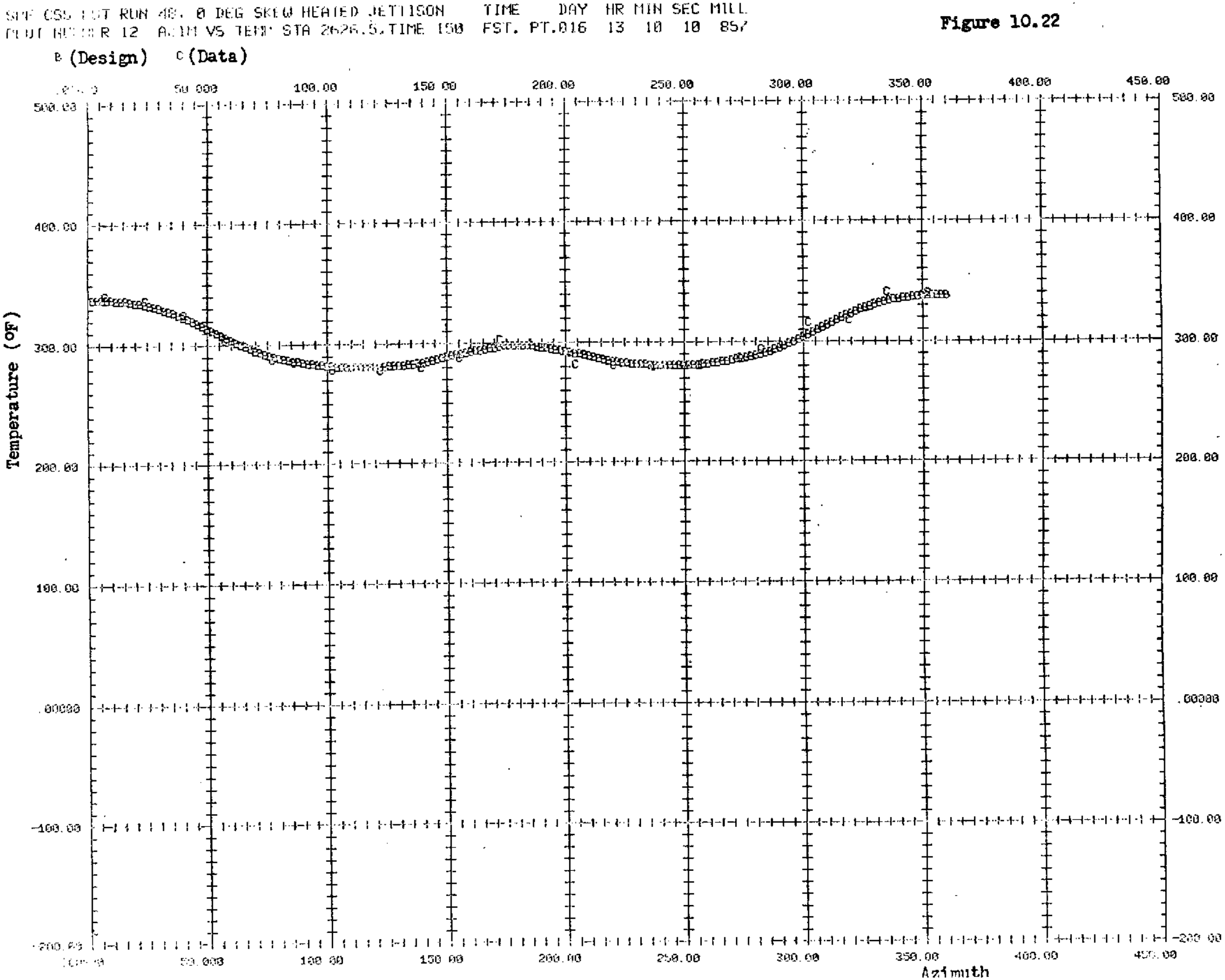


Figure 10.22



SMF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS TEMP STA 2626.5,TIME 150 FST. PT.016 13 10 10 857
B (Design) C (Data)
Temperature (°F)
Azimuth
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

SMF CSS FST RUN 49. 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 12   AZIM VS TEMP STA 2676.5.TIME 200 FST. PT.016 13 10 10 857

Figure 10.23

B (Design)   C (Data)

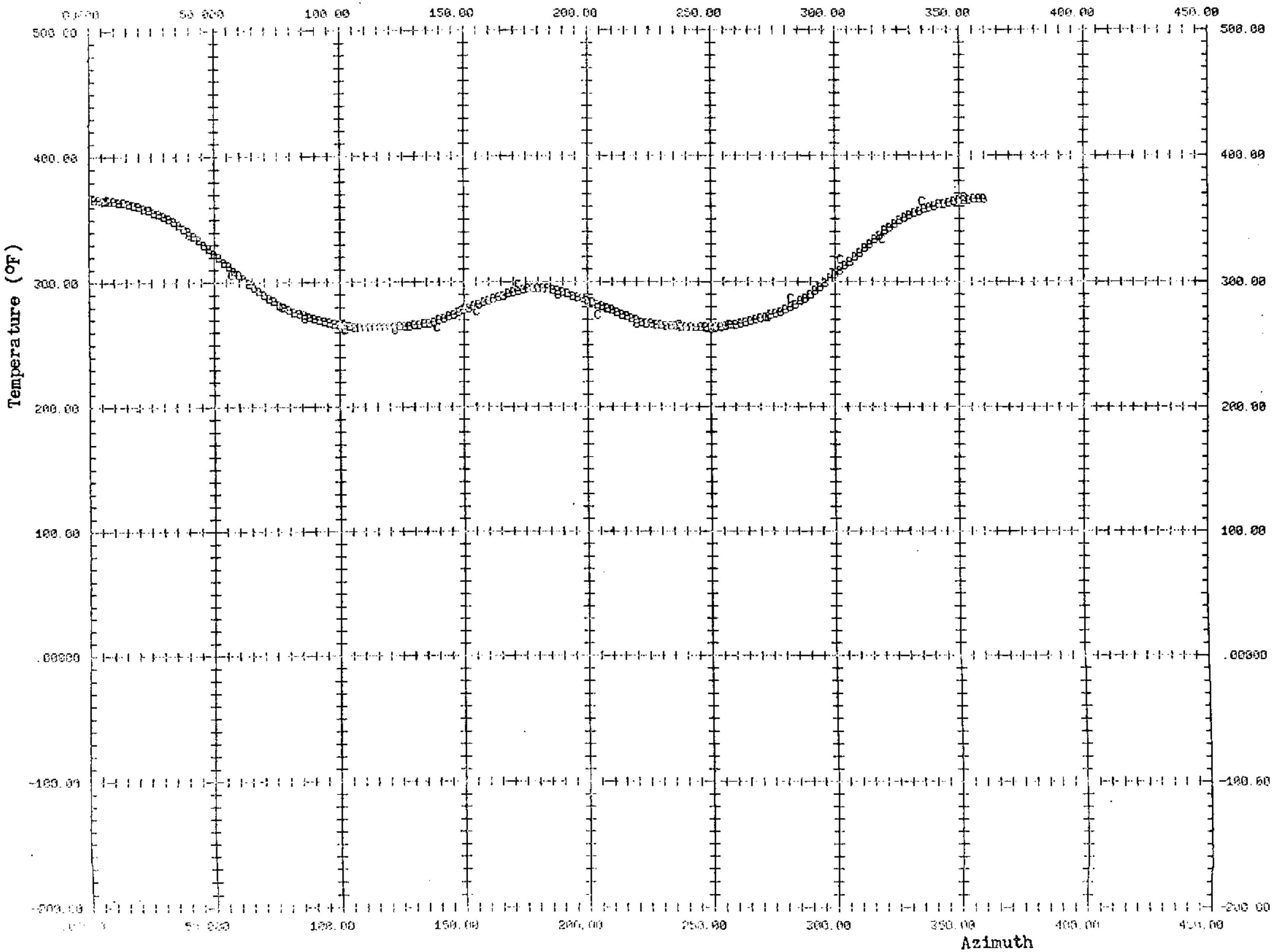
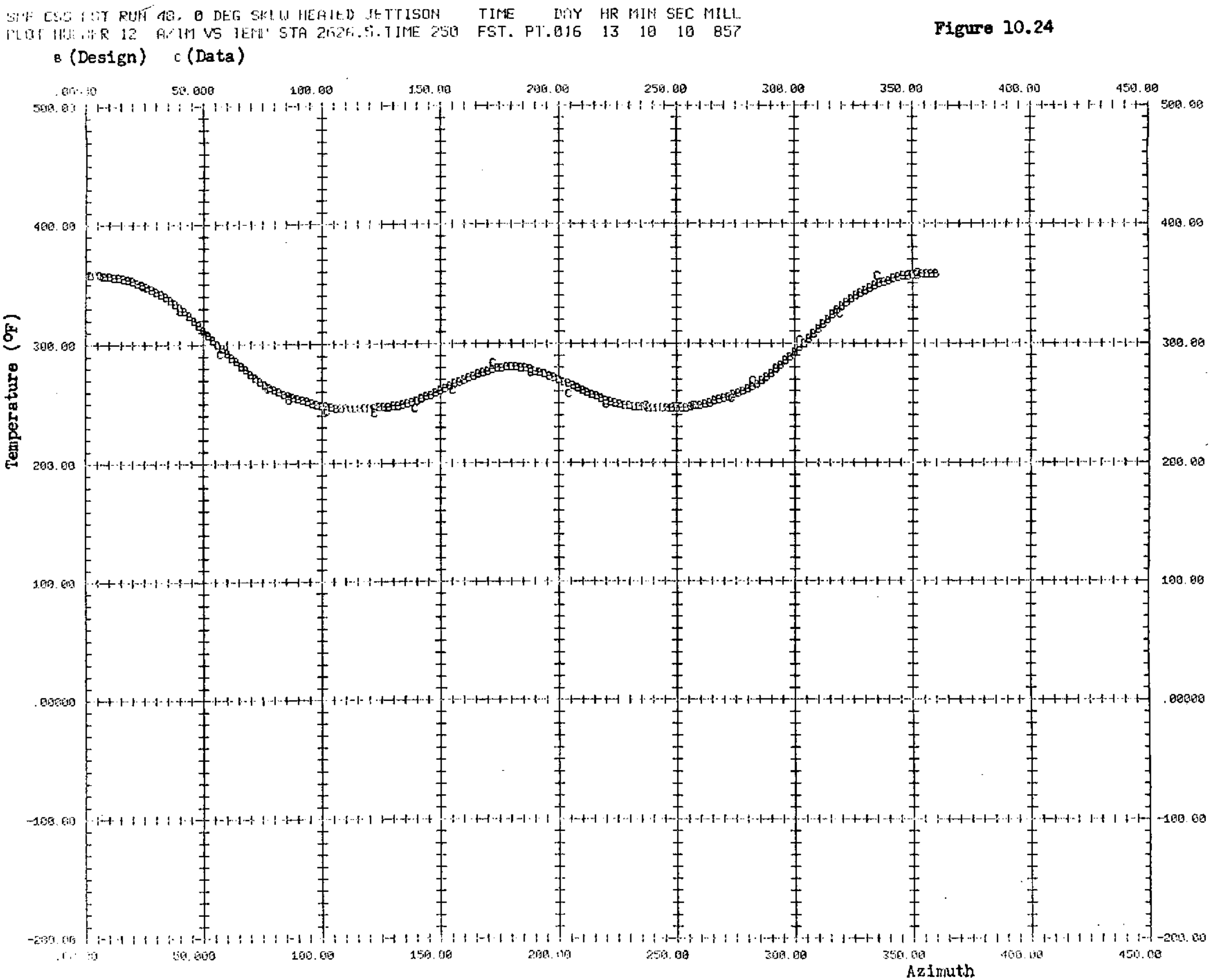


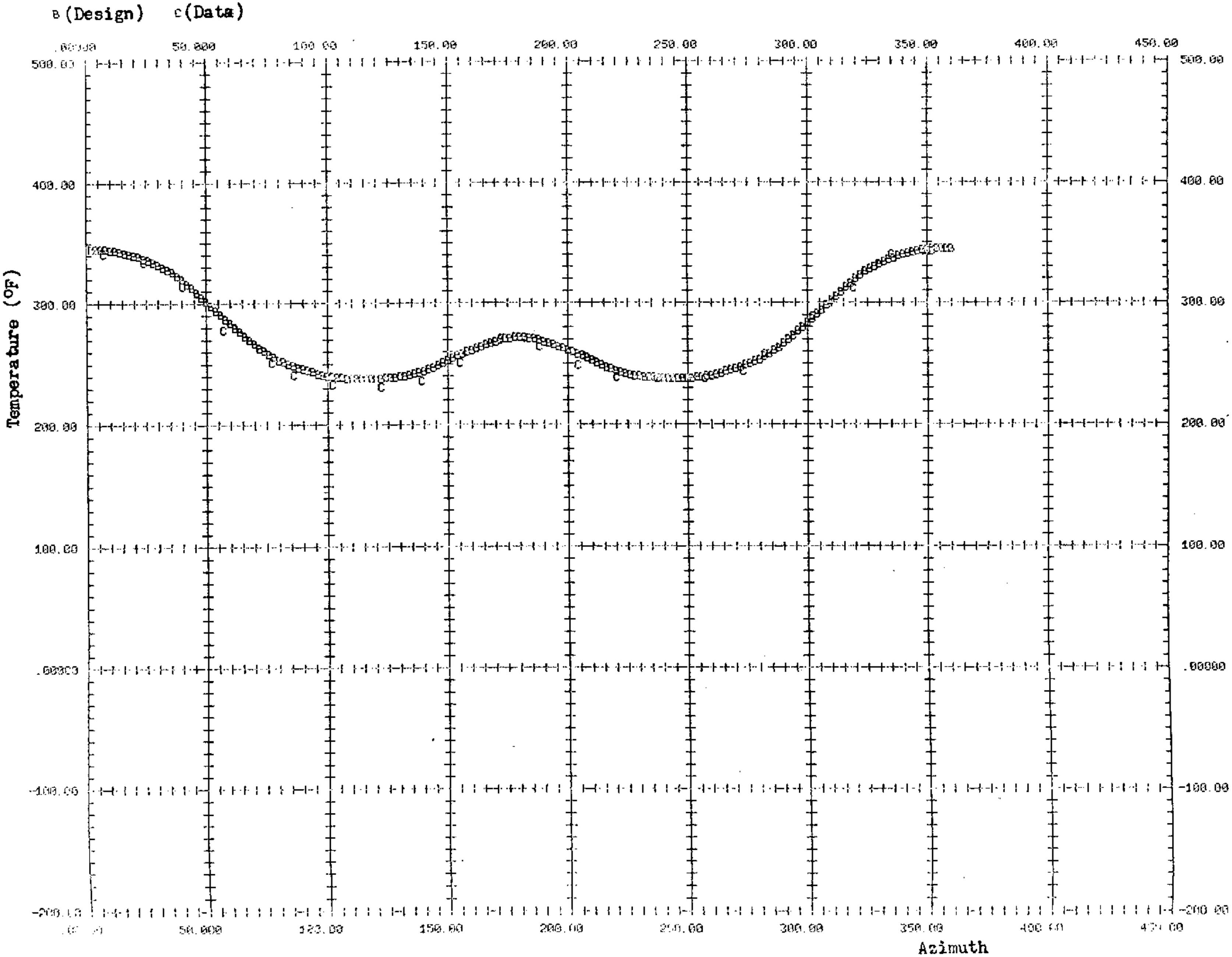
Figure 10.24



SMF CSS FST RUN 40, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS TEMP STA 2626.5.TIME 250 FST. PT.016 13 10 10 857
B (Design) C (Data)
Temperature (°F)
Azimuth
.00000
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
-100.00
-200.00

SMF CSS FST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS TEMP STA 2626.5,TIME 275 FST. PT.016 13 10 10 857

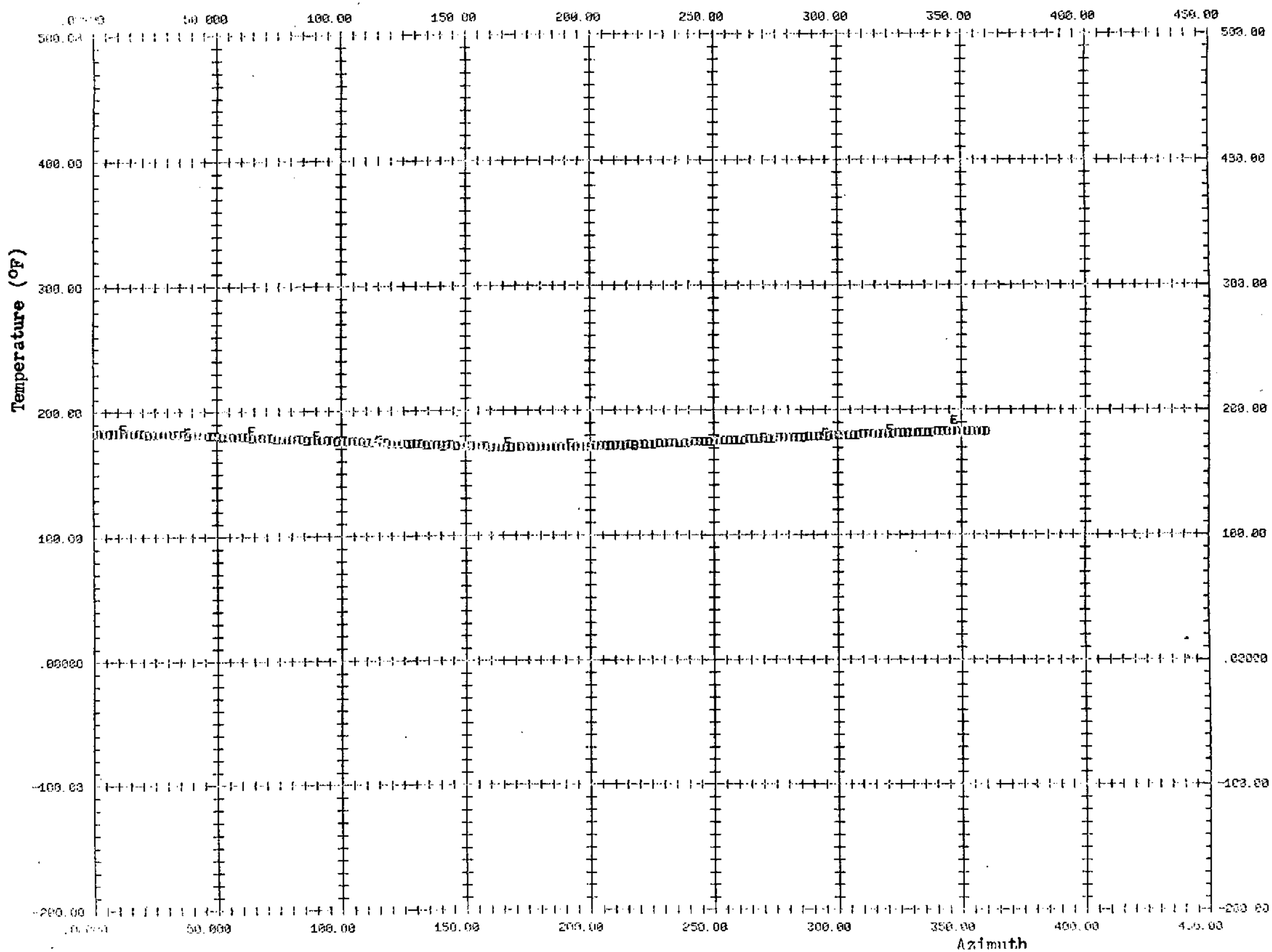
Figure 10.25



SMF CSS [illegible] RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 14 [illegible] VS TEMP-STA 2723.5.TIME 100 FST. PT.016 13 10 10 857

Figure 10.26

D (Design) E (Data)



SPF CSS IST RUN 49, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 14 AZIM VS TEMP STA 2723.5,TIME 150 FST. PT.016 13 10 10 857

Figure 10.27

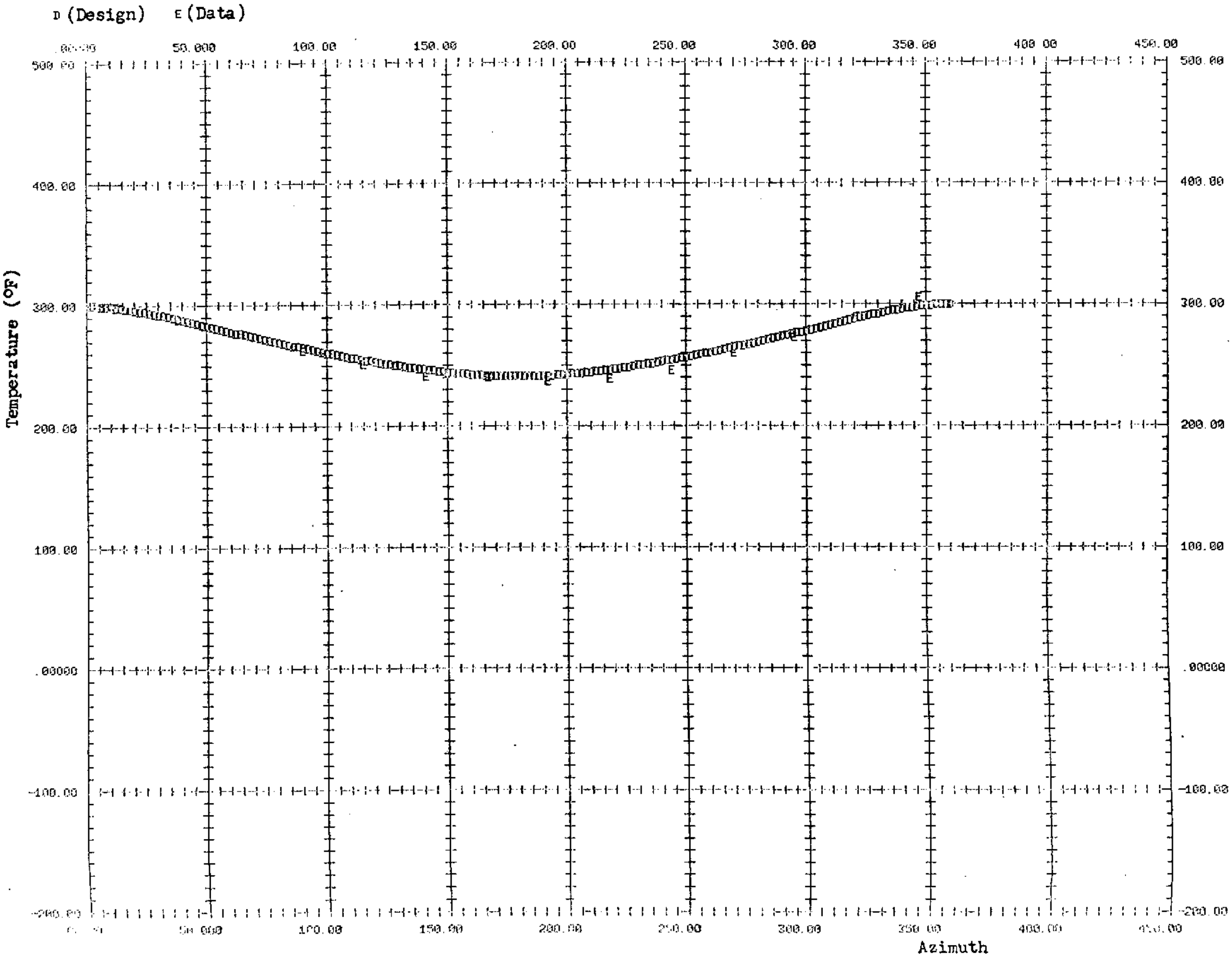
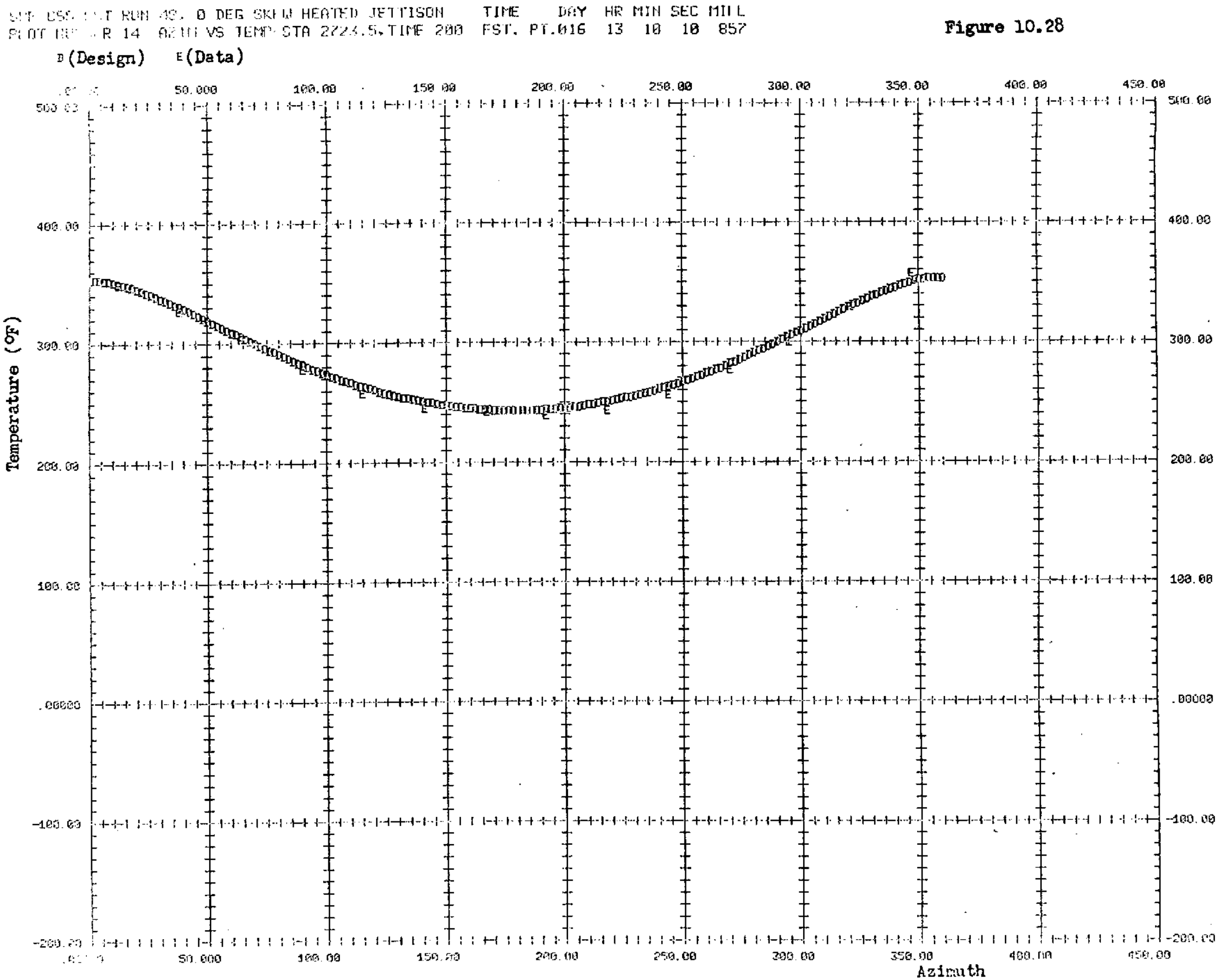
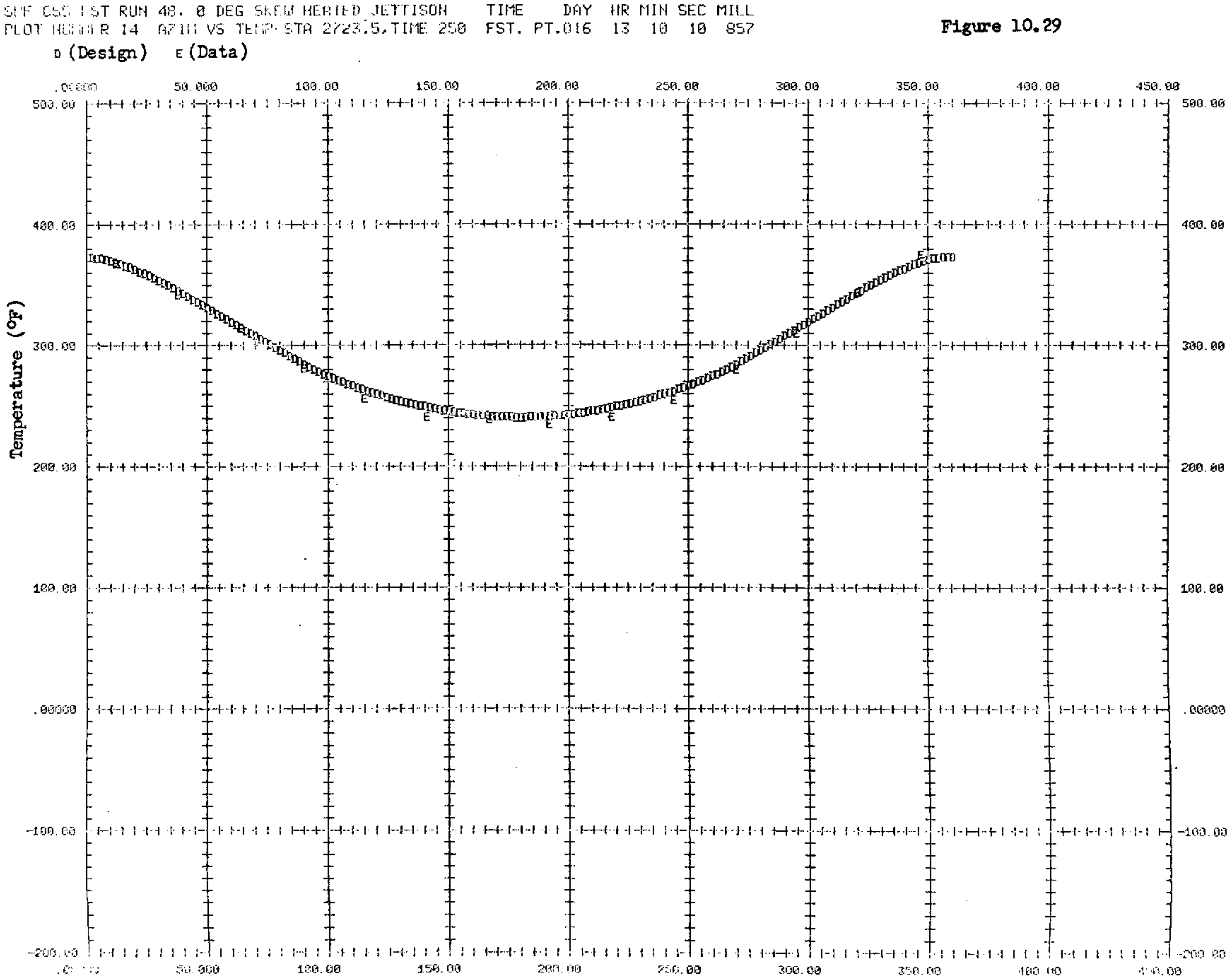


Figure 10.28



SRB DSS ... RUN 49, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT ... R 14 AZIM VS TEMP STA 2724.5, TIME 200 FST. PT.016 13 10 10 857
D (Design) E (Data)
Temperature (°F)
Azimuth
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

Figure 10.29

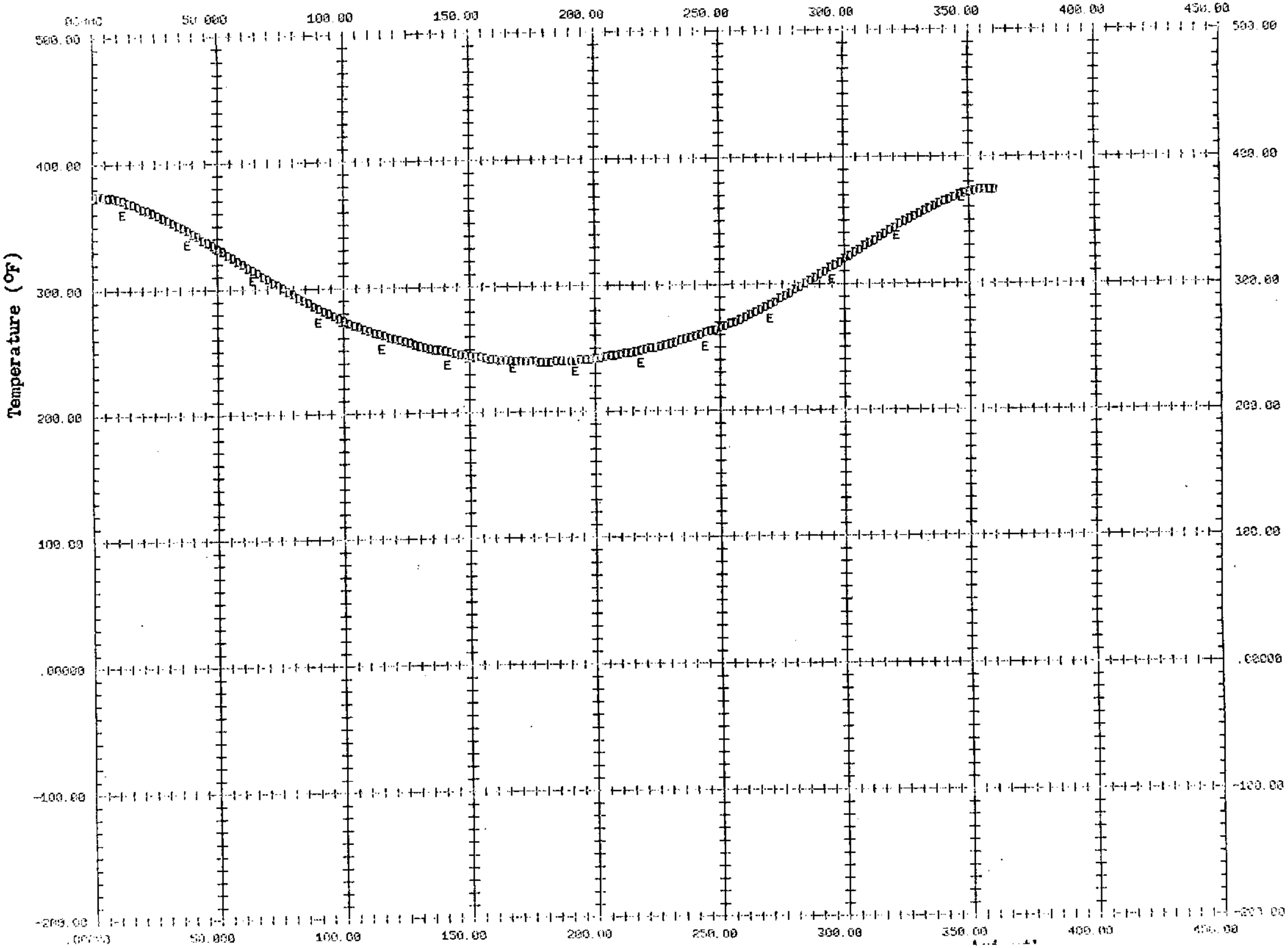


SPF CSC TST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 14 AZIM VS TEMP STA 2723.5,TIME 250 FST. PT.016 13 10 10 857
D (Design) E (Data)
Temperature (°F)
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00
.00000
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

SMF CSC TEST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 14 AZIM VS TEMP STA 2223.5,TIME 275 TST. PT.016 13 10 10 857

Figure 10.30

B (Design) E (Data)



SPF CSS-FST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 16 AZIM VS TEMP STA 2792.0,TIME 100 FST. PT.016 13 10 10 857

Figure 10.31

F (Design) G (Data)

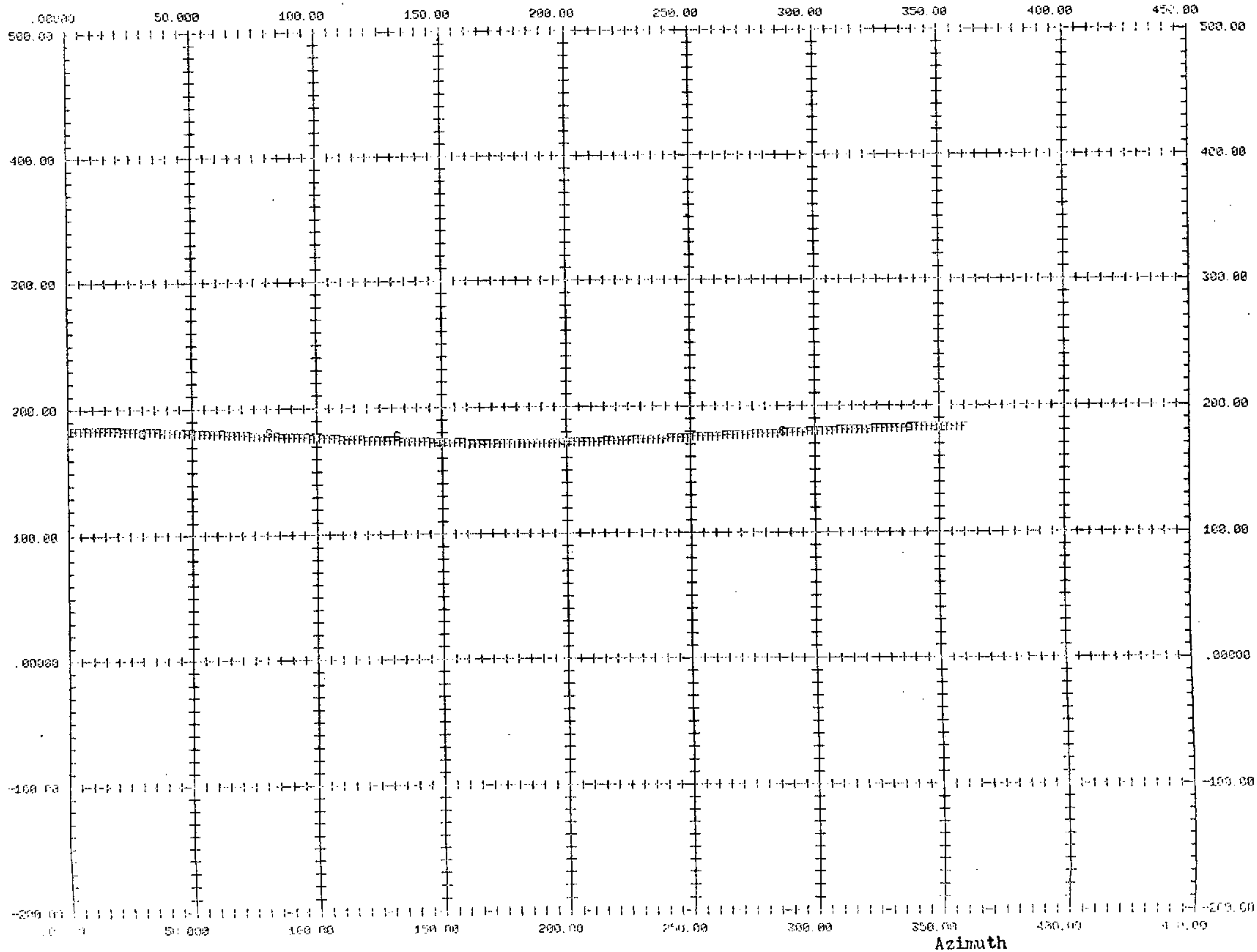
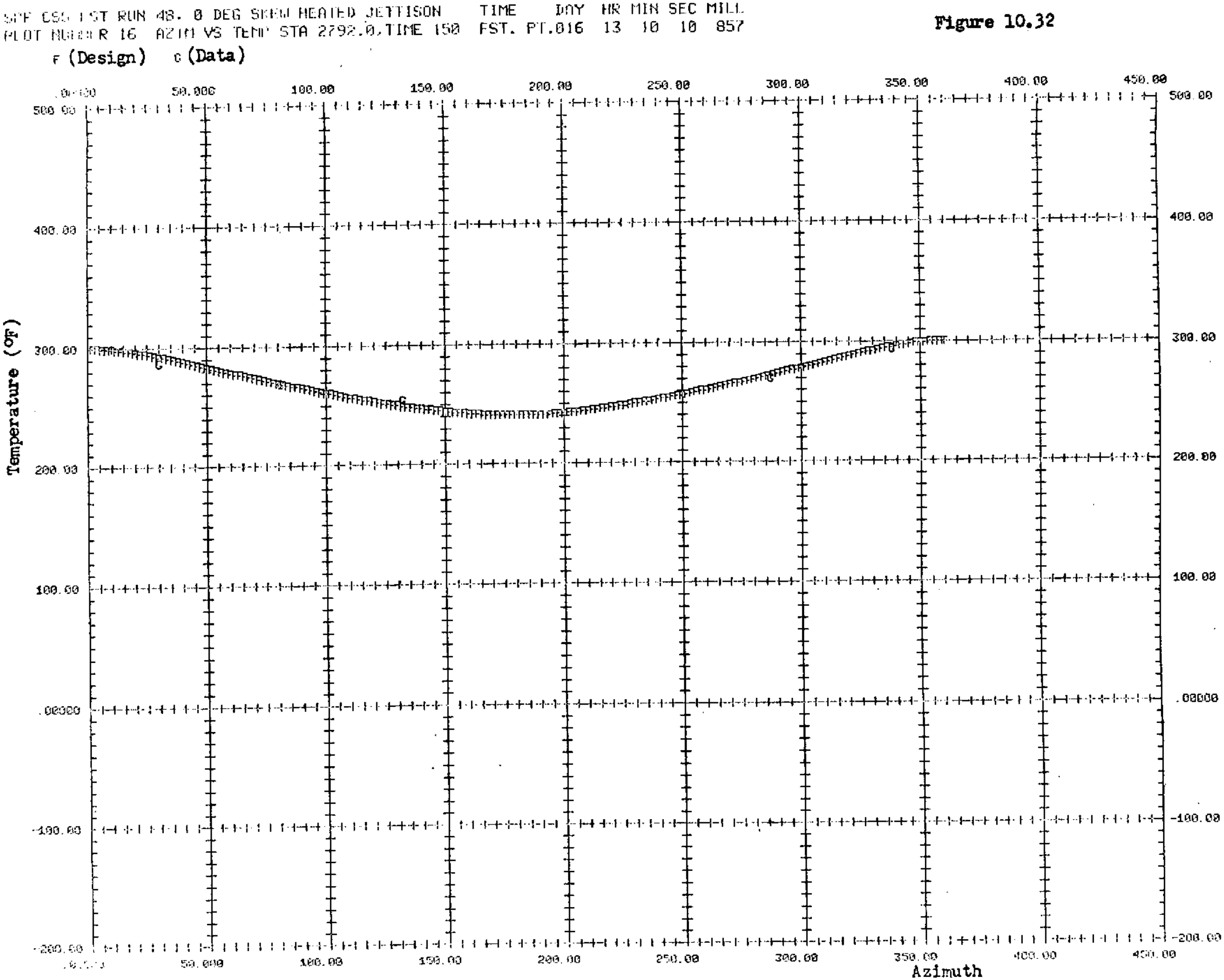


Figure 10.32

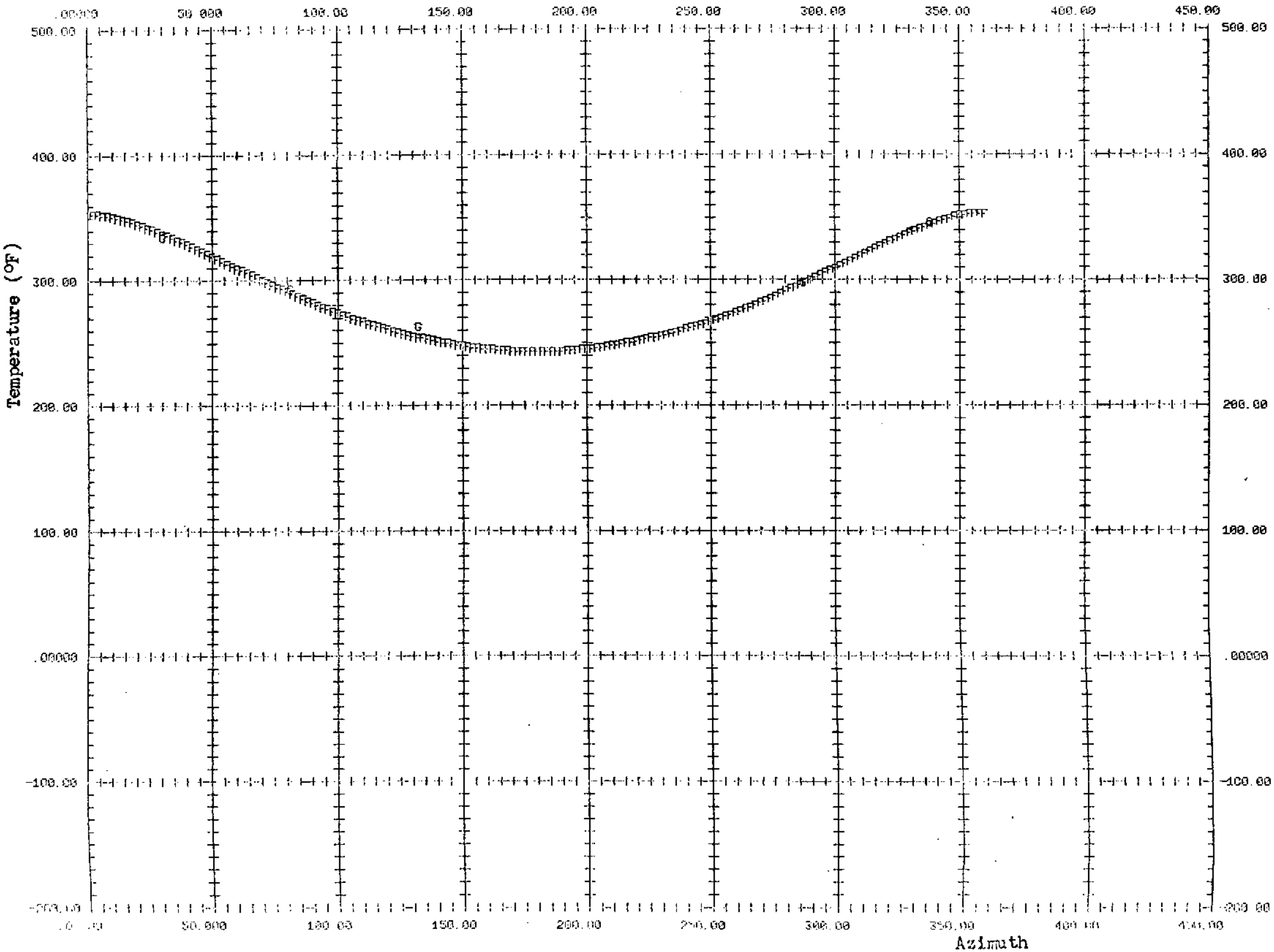


SPF CSS FST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 16 AZIM VS TEMP STA 2792.0,TIME 150 FST. PT.016 13 10 10 857
F (Design) C (Data)
Temperature (°F)
Azimuth

SPF CSS TST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 16 AZIM VS TEMP STA 2792.0,TIME 200 TST. PT.016 13 10 10 857

Figure 10.33

F (Design) G (Data)



SRF CSS TST RUN 48. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 16 AZIM VS TEMP STA 2792.0,TIME 250 FST. PT.016 13 10 10 857

Figure 10.34

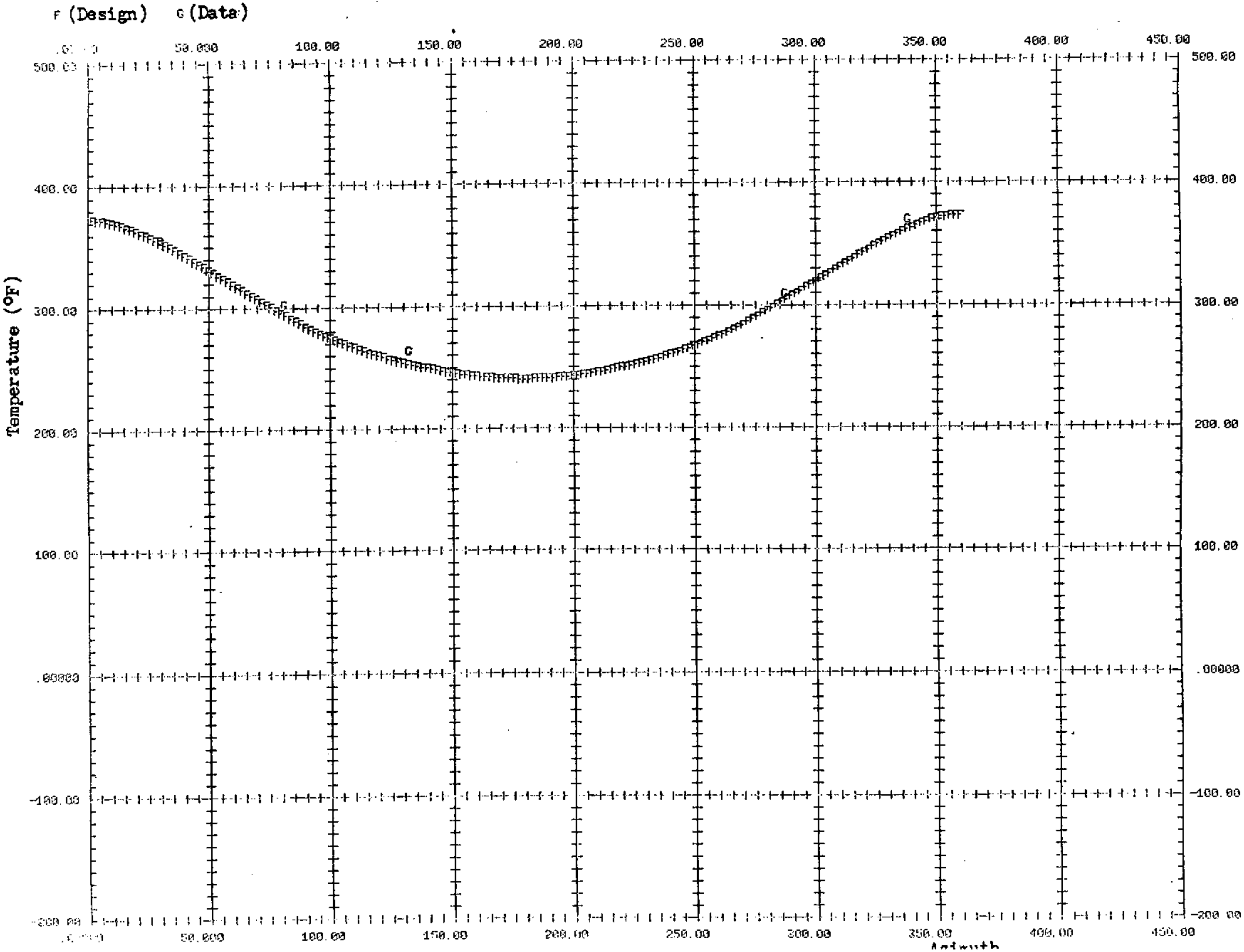
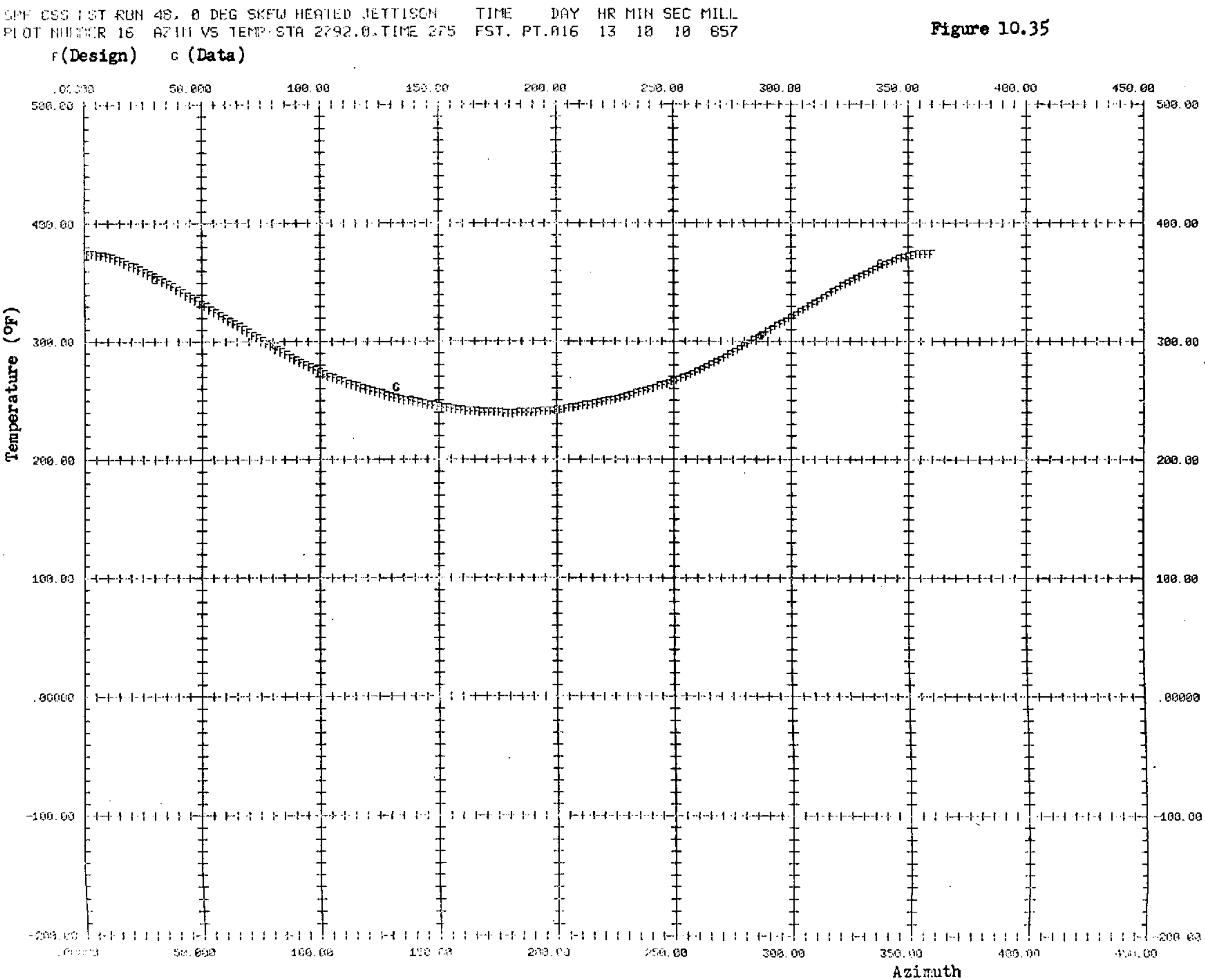


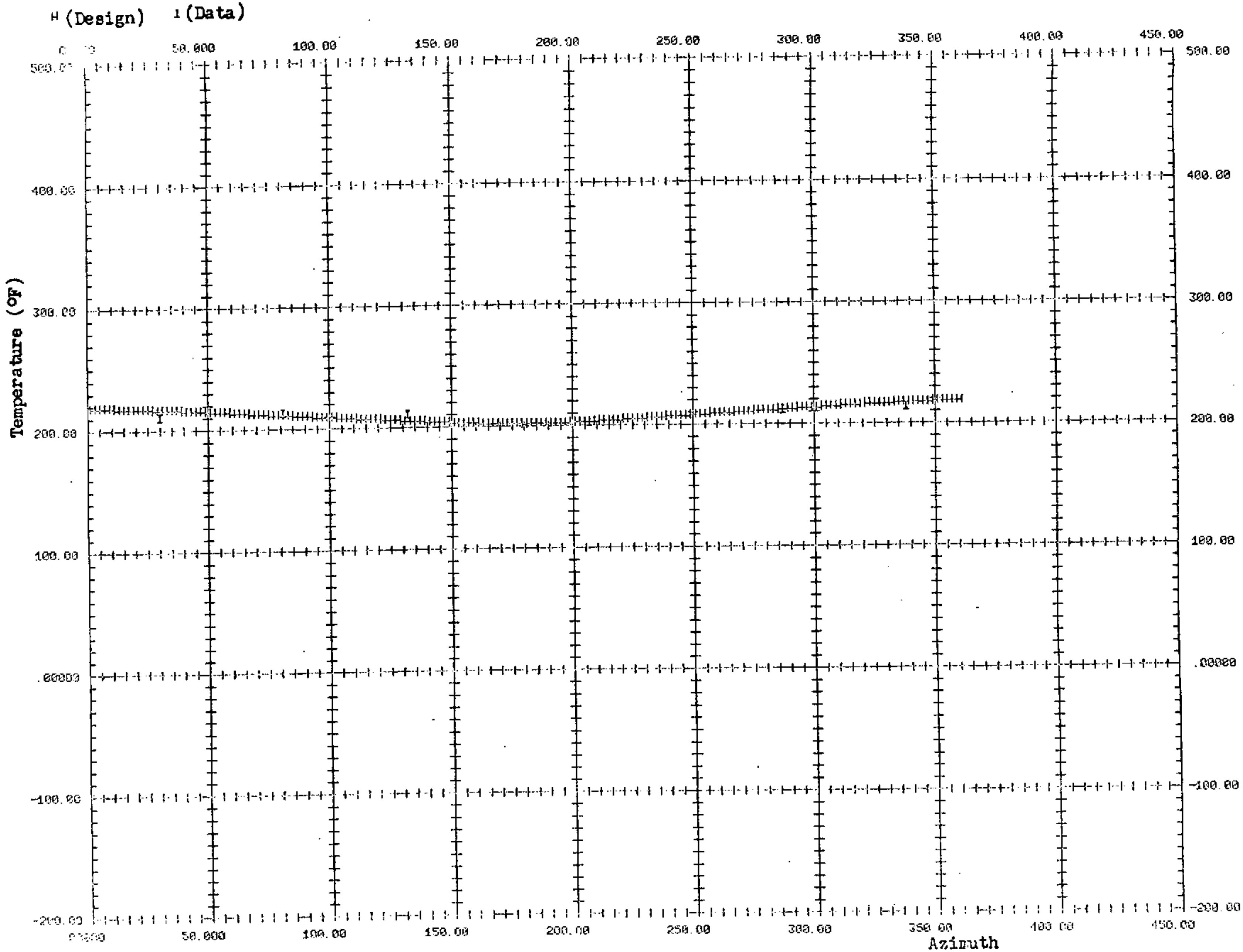
Figure 10.35



SPF CSS TST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 16 AZIM VS TEMP STA 2792.0, TIME 275 FST. PT.016 13 10 10 857
F(Design) G (Data)
Temperature (°F)
Azimuth

SMF CNC TST RUN 48. 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 18 AZIM VS TEMP-STA 2820.0,TIME 100 FST. PT.016 13 10 10 857

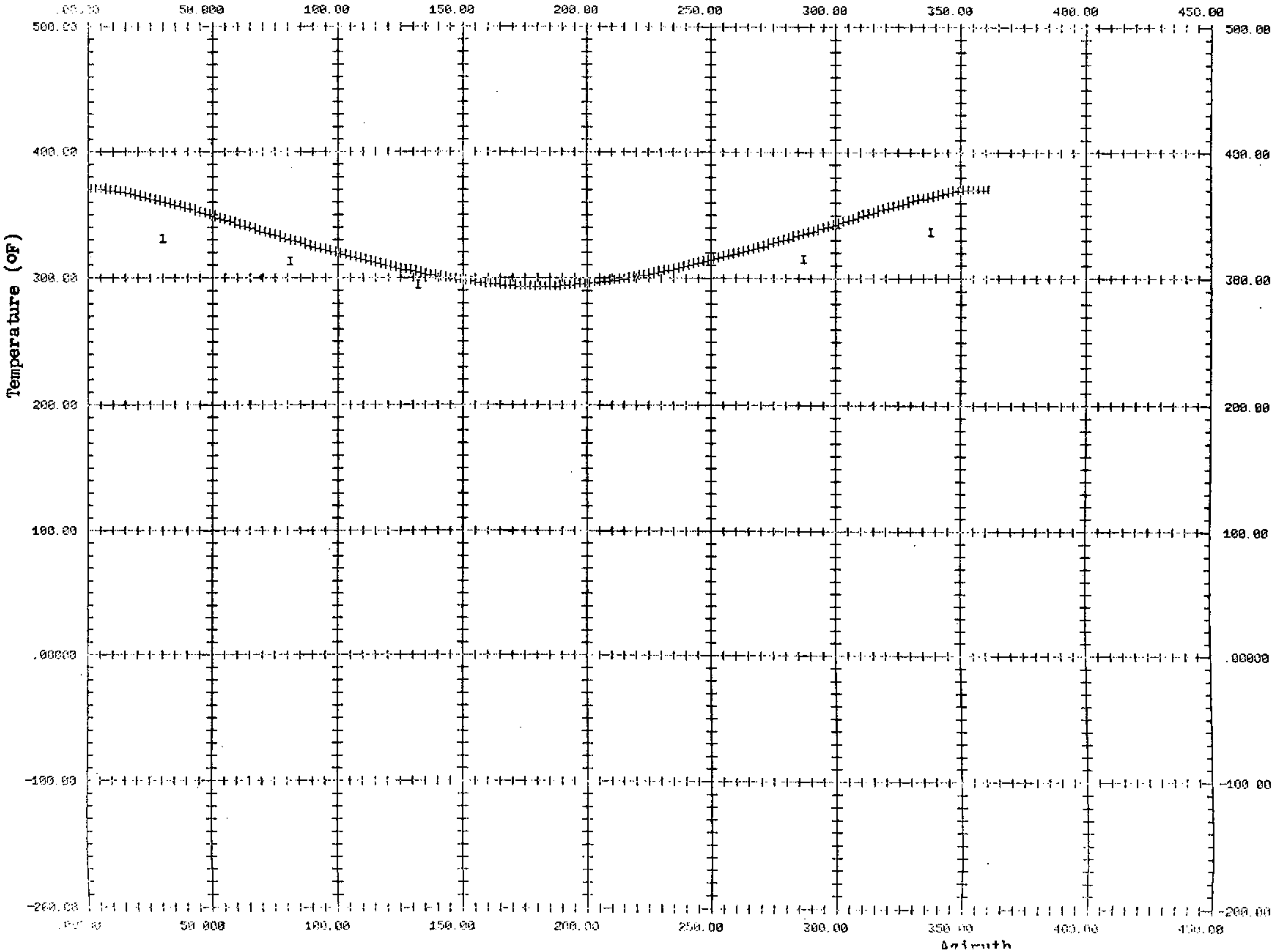
Figure 10.36



SPF CSS 1ST RUN 48, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 18 AZIM VS TEMP-STA 2820.0,TIME 150 FST. PT.016 13 10 10 857

Figure 10.37

H **(Design)** I **(Data)**



SMF CSS FST RUN 40. 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 18 AZIM VS TEMP STA 2870.0,TIME 200 FST. PT.016 13 10 10 857

Figure 10.38

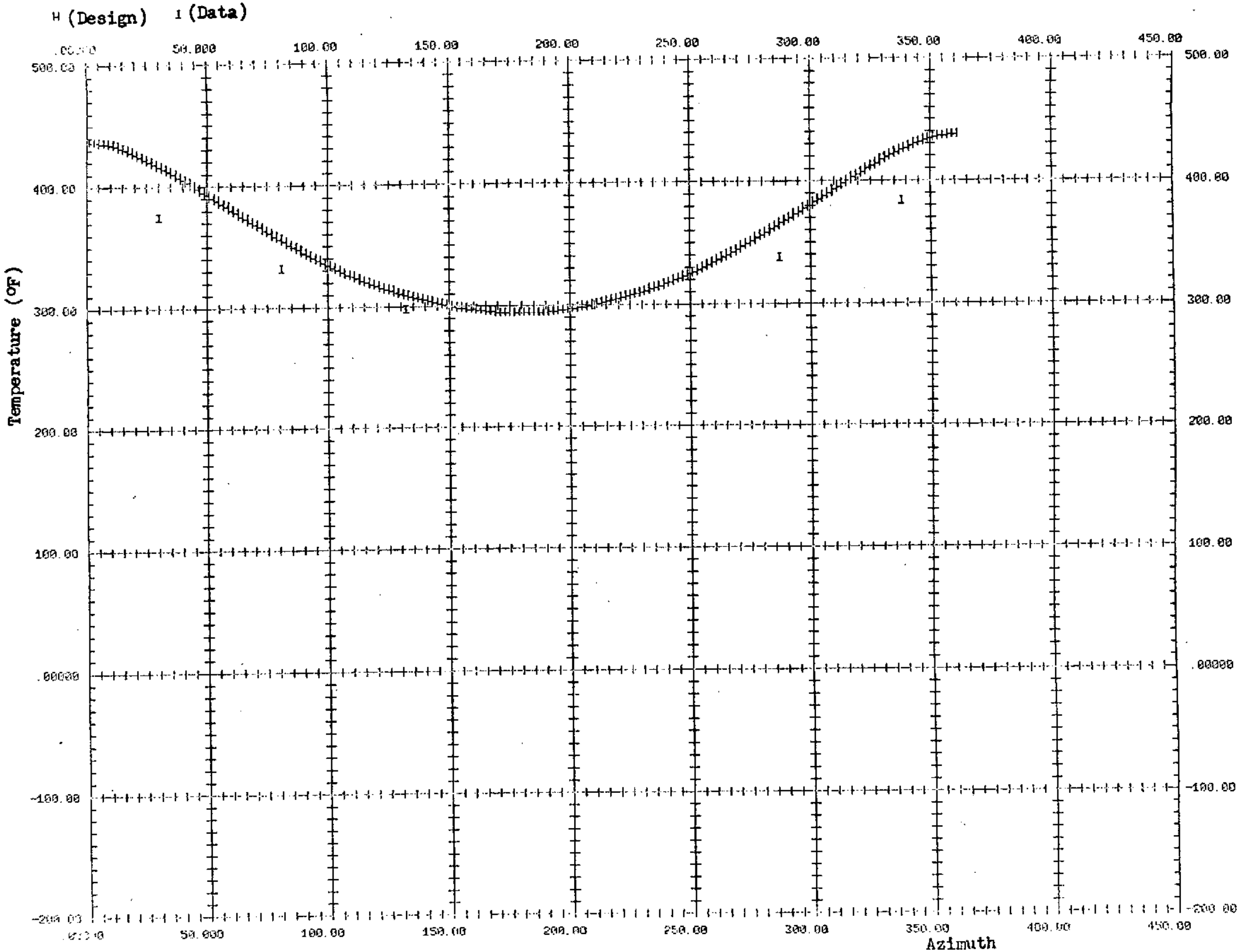
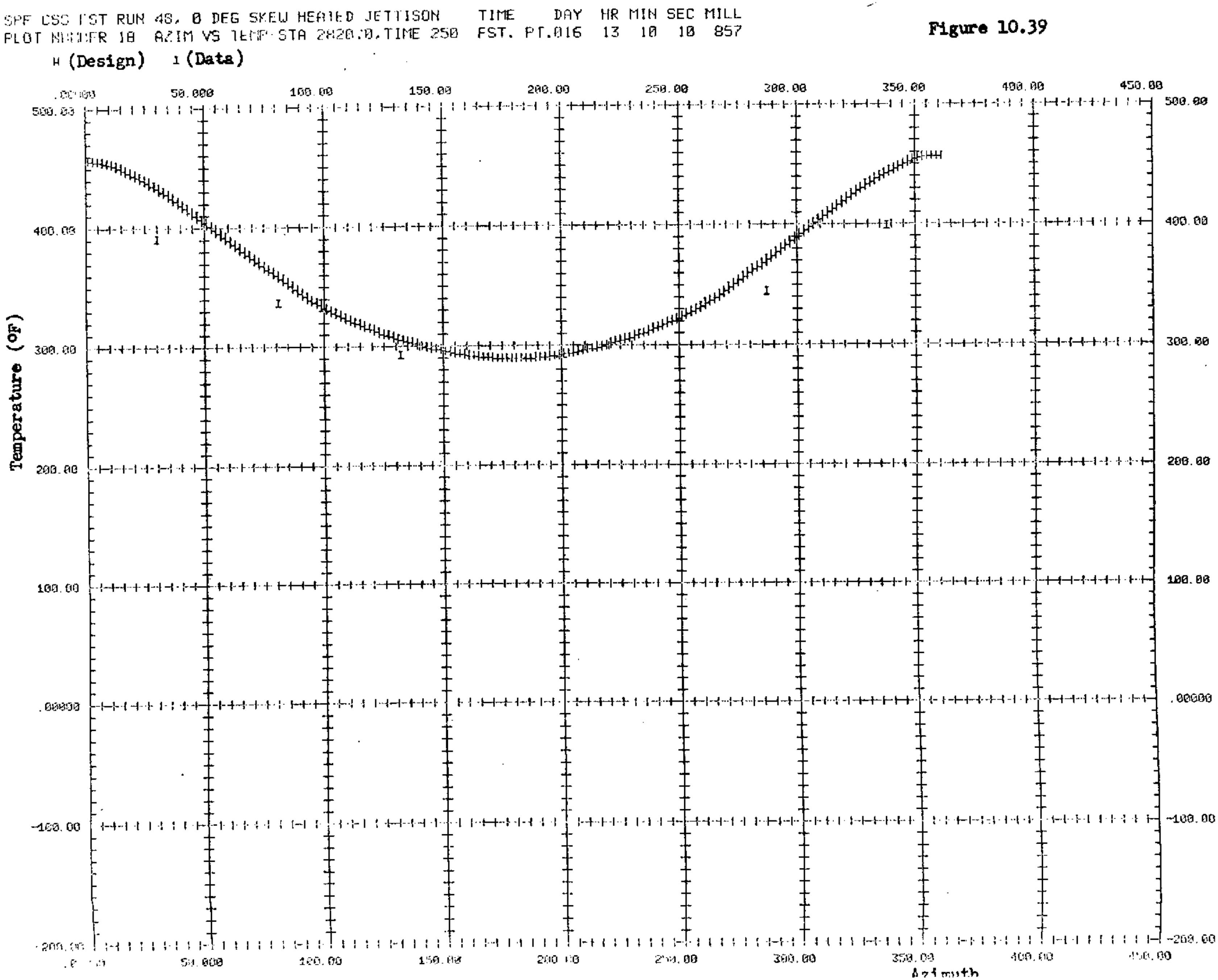
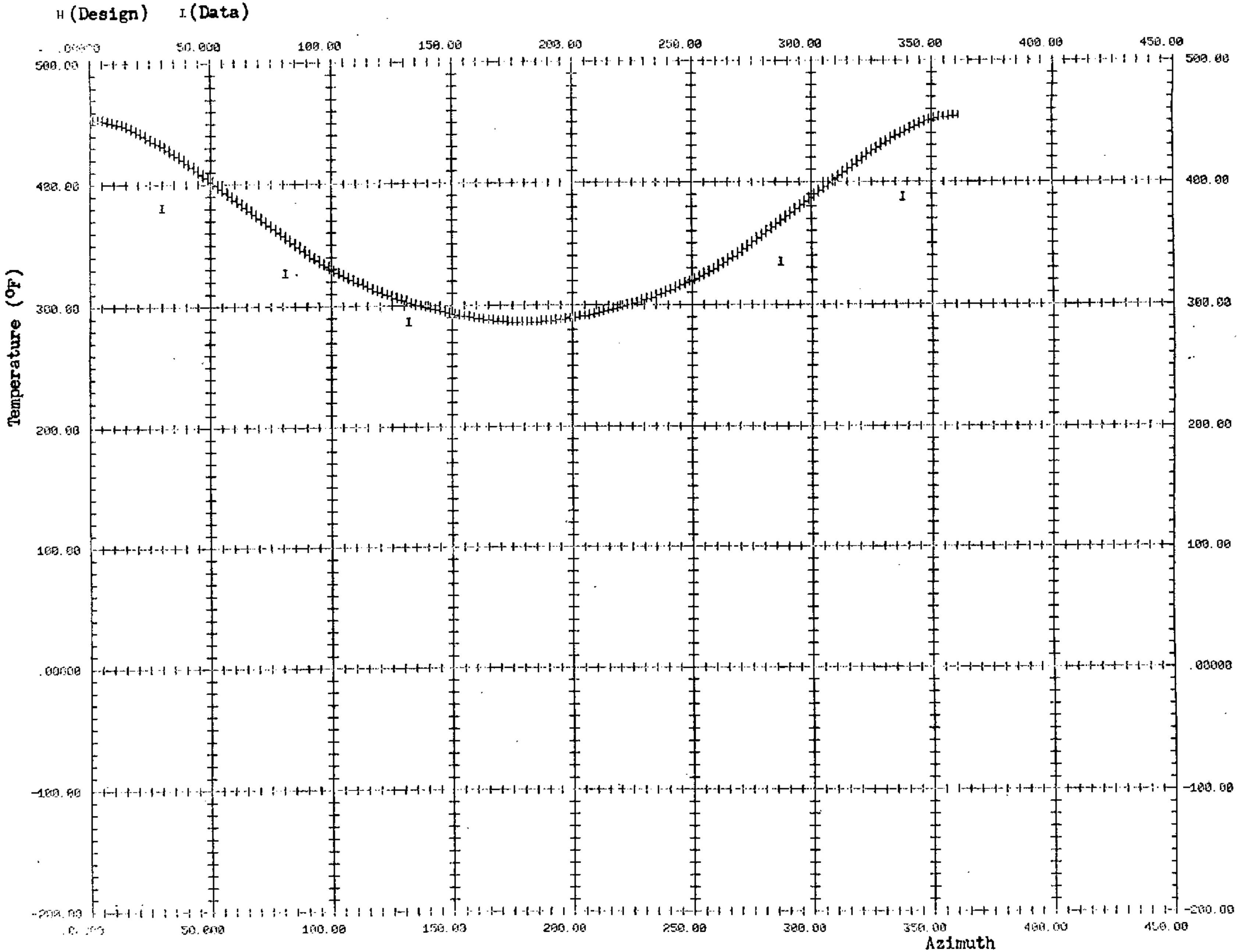


Figure 10.39


SPF CSS FST RUN 48, 0 DEG SKEW HEATED JETTISON TIME DAY HR MIN SEC MILL
PLOT NUMBER 18 AZIM VS TEMP STA 2820.0, TIME 250 FST. PT.016 13 10 10 857
H (Design) I (Data)
Temperature (oF)
Azimuth
500.00
400.00
300.00
200.00
100.00
.00000
-100.00
-200.00
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00

SMF CSS TGT RUN 48, 0 DEG SKEW HEATED JETTISON   TIME   DAY HR MIN SEC MILL
PLOT NUMBER 18 AZIM VS TEMP STA 2020.0.TIME 2/5 FST. PT.016 13 10 10 857

Figure 10.40



Figures 11.1 thru 11.15.

Circumferential deflection and design temperature distributions.

I

SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 100 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS DEFLX100.D TEMP-STA 2377 FST. PT.016 13 10 10 857

Figure 11.1

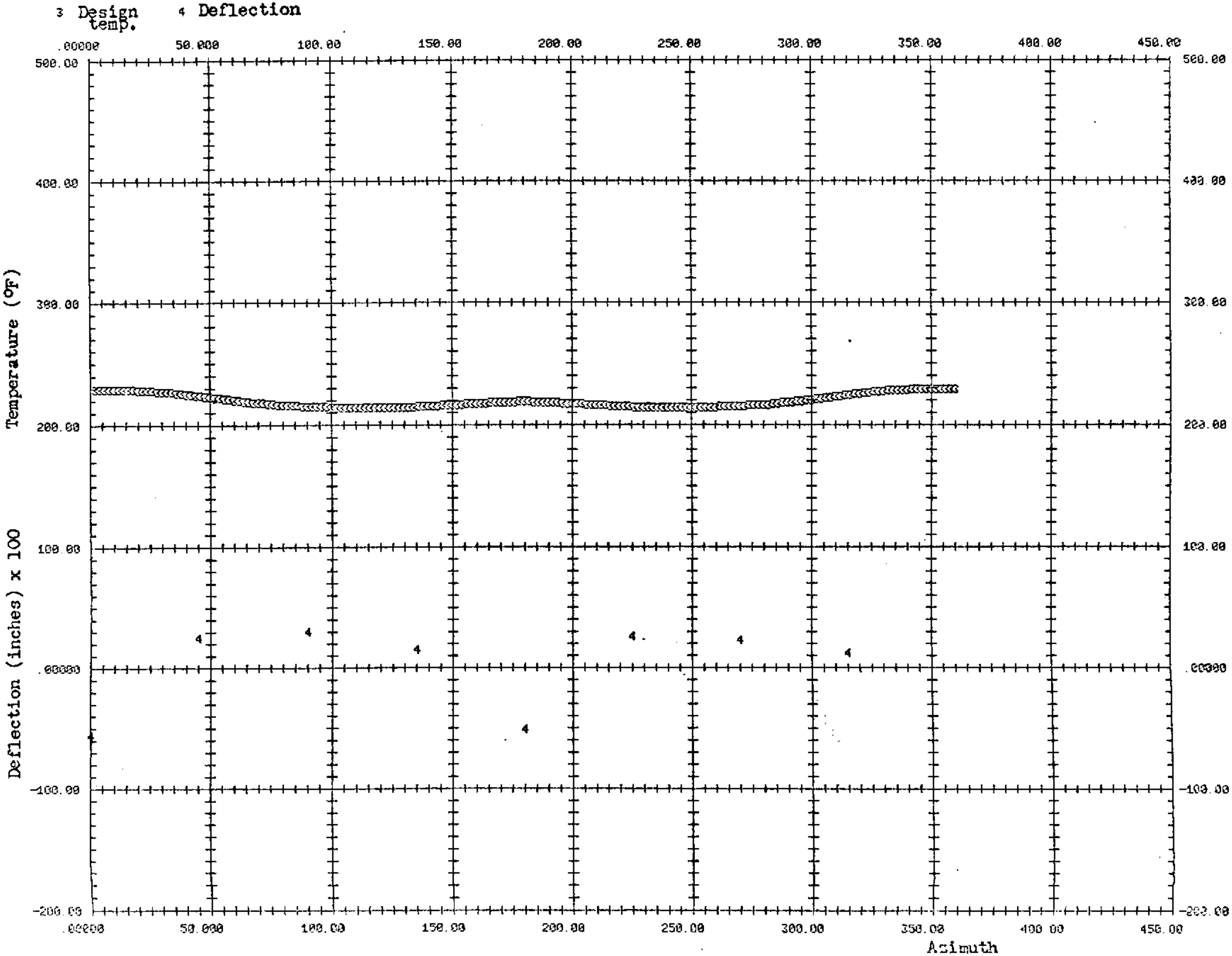
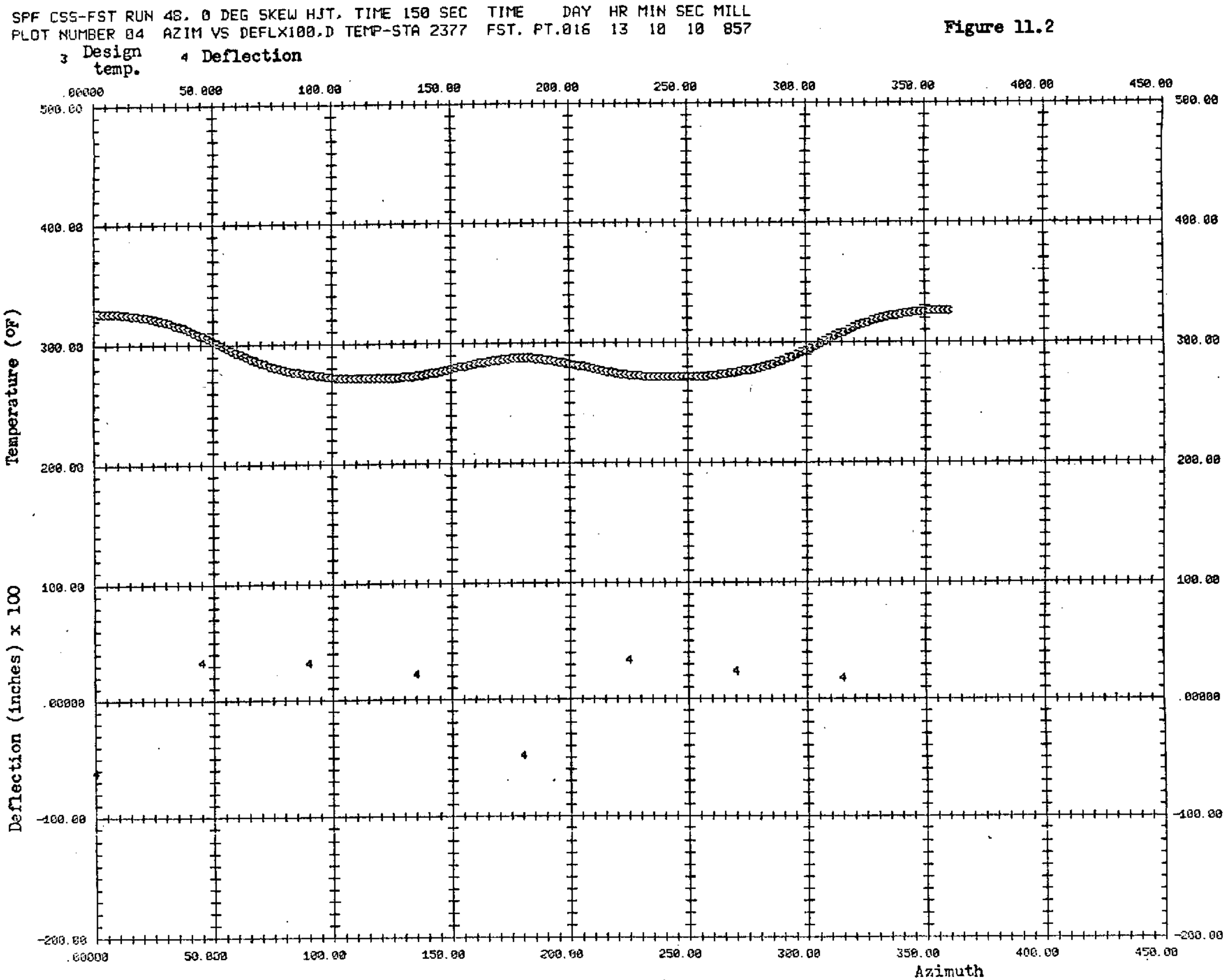


Figure 11.2



SPF CSS-FST RUN 48. 0 DEG SKEW HJT. TIME 150 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS DEFLX100.D TEMP-STA 2377 FST. PT.016 13 10 10 857
3 Design temp.
4 Deflection
Temperature (oF)
Deflection (inches) x 100
Azimuth
.00000
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
-100.00
-200.00

SPF CSS-FST RUN 48. 0 DEG SKEW HJT. TIME 200 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS DEFLX100.D TEMP-STA 2377 FST. PT.016 13 10 10 857

Figure 11.3

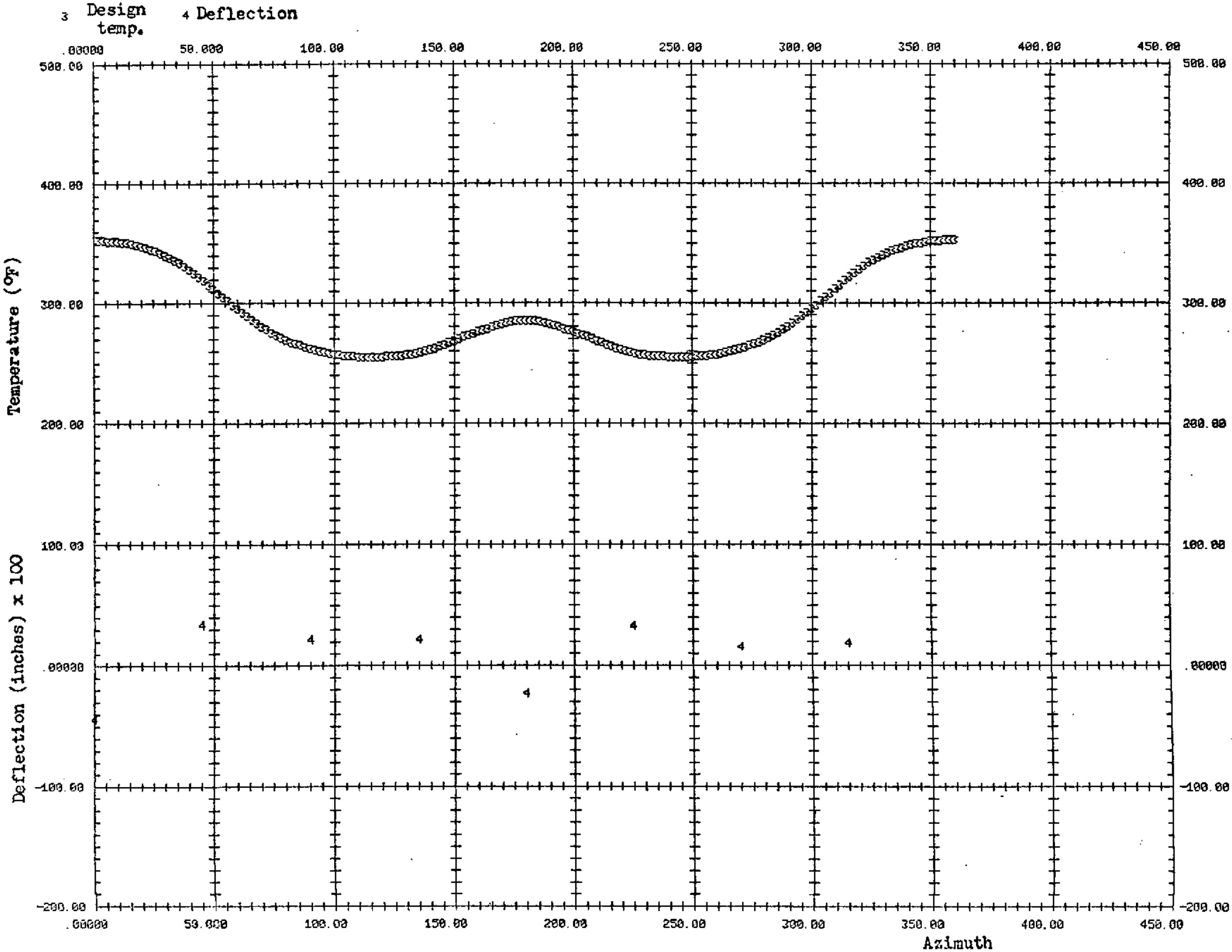
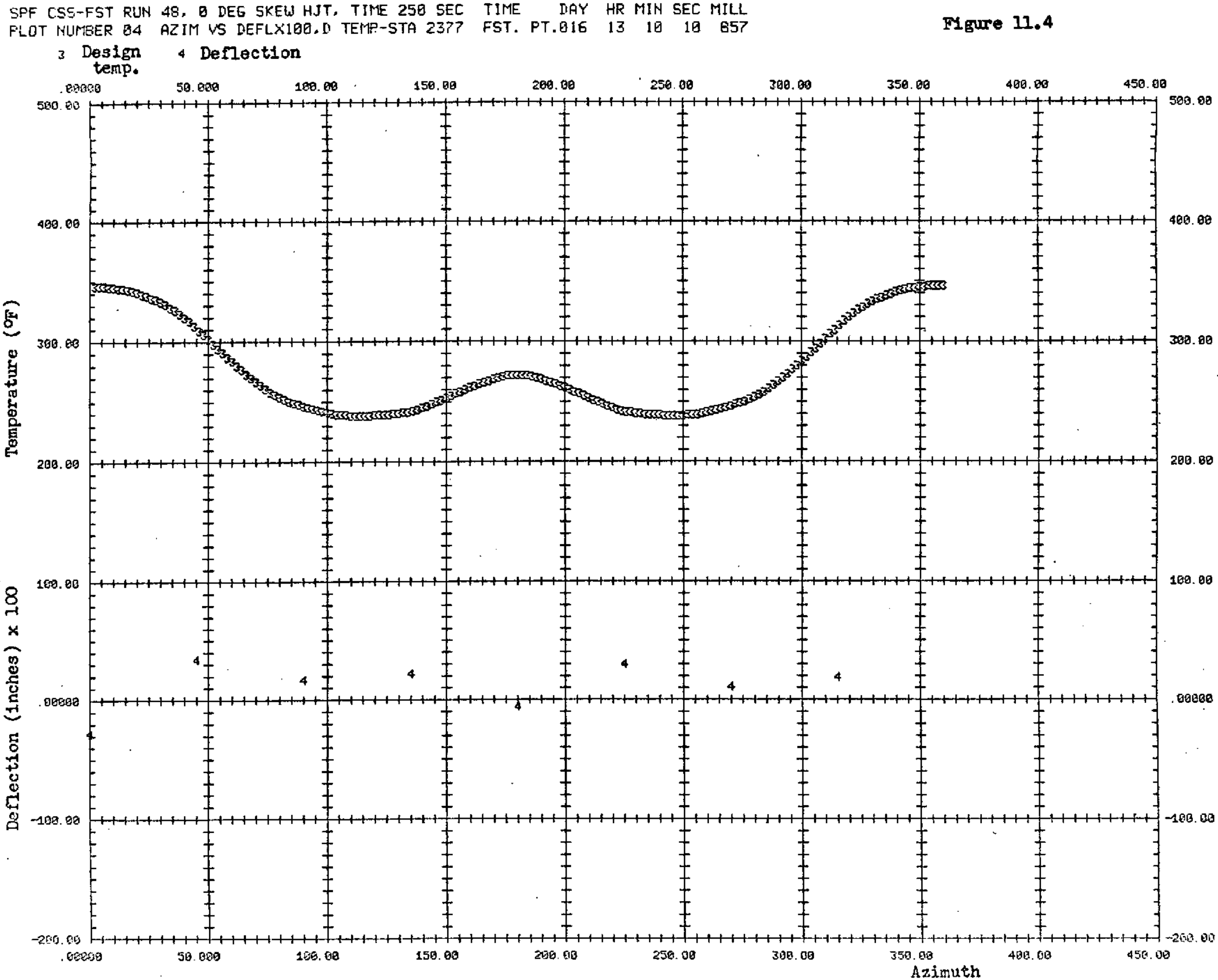


Figure 11.4


SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 250 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS DEFLX100.D TEMP-STA 2377 FST. PT.016 13 10 10 657
3 Design temp.
4 Deflection
Temperature (°F)
Deflection (inches) x 100
Azimuth
.00000
50.000
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
500.00
-100.00
-200.00

SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 275 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 04 AZIM VS DEFLX100,D TEMP-STA 2377 FST. PT.016 13 10 10 857

Figure 11.5

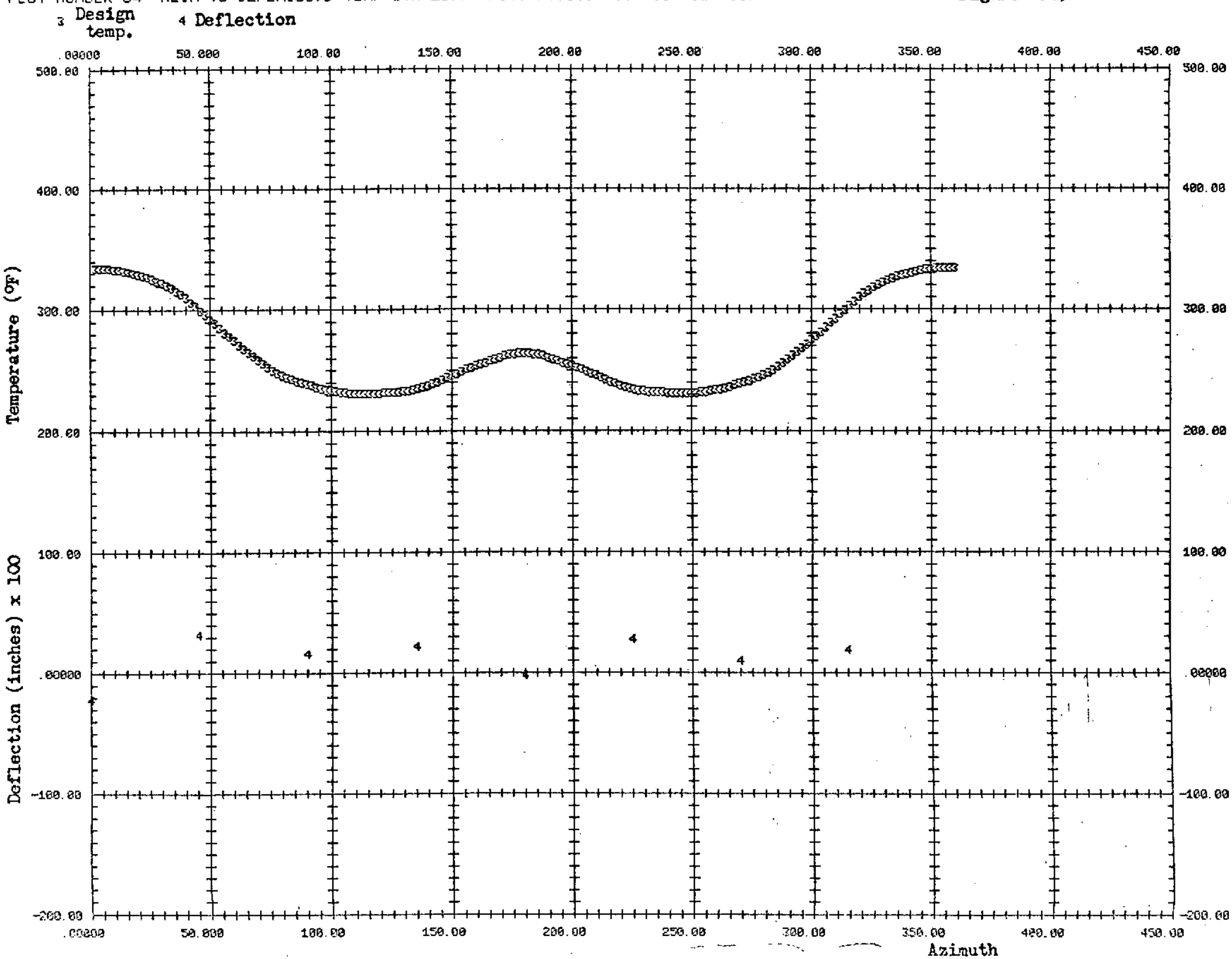
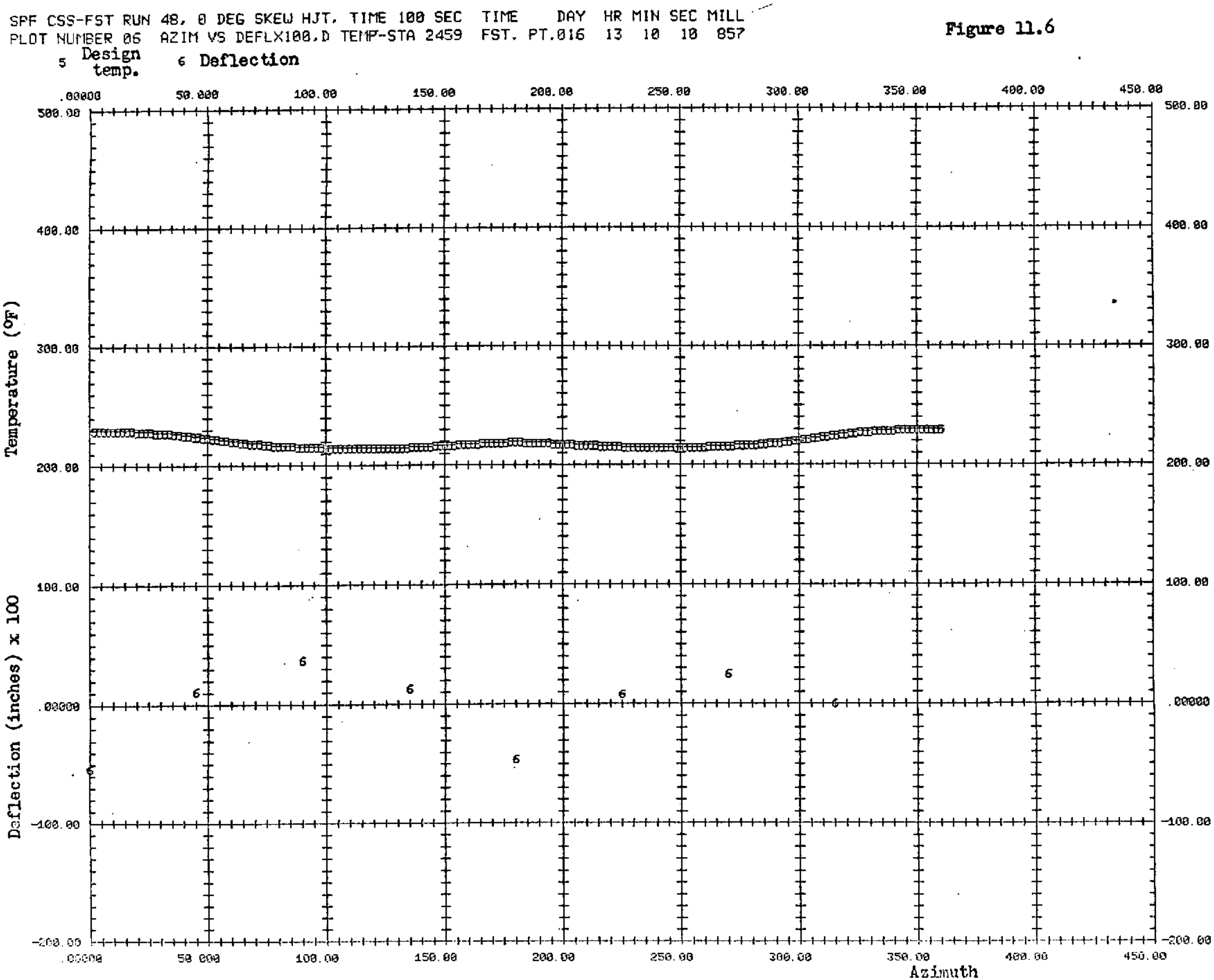


Figure 11.6


SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 100 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 AZIM VS DEFLX100,D TEMP-STA 2459 FST. PT.016 13 10 10 857
5 Design temp.
6 Deflection
Temperature (°F)
Deflection (inches) x 100
Azimuth
.00000
50.000
100.00
150.00
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250.00
300.00
350.00
400.00
450.00
500.00
-100.00
-200.00

SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 150 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 AZIM VS DEFLX100.D TEMP-STA 2459 FST. PT.016 13 10 10 857

Figure 11.7

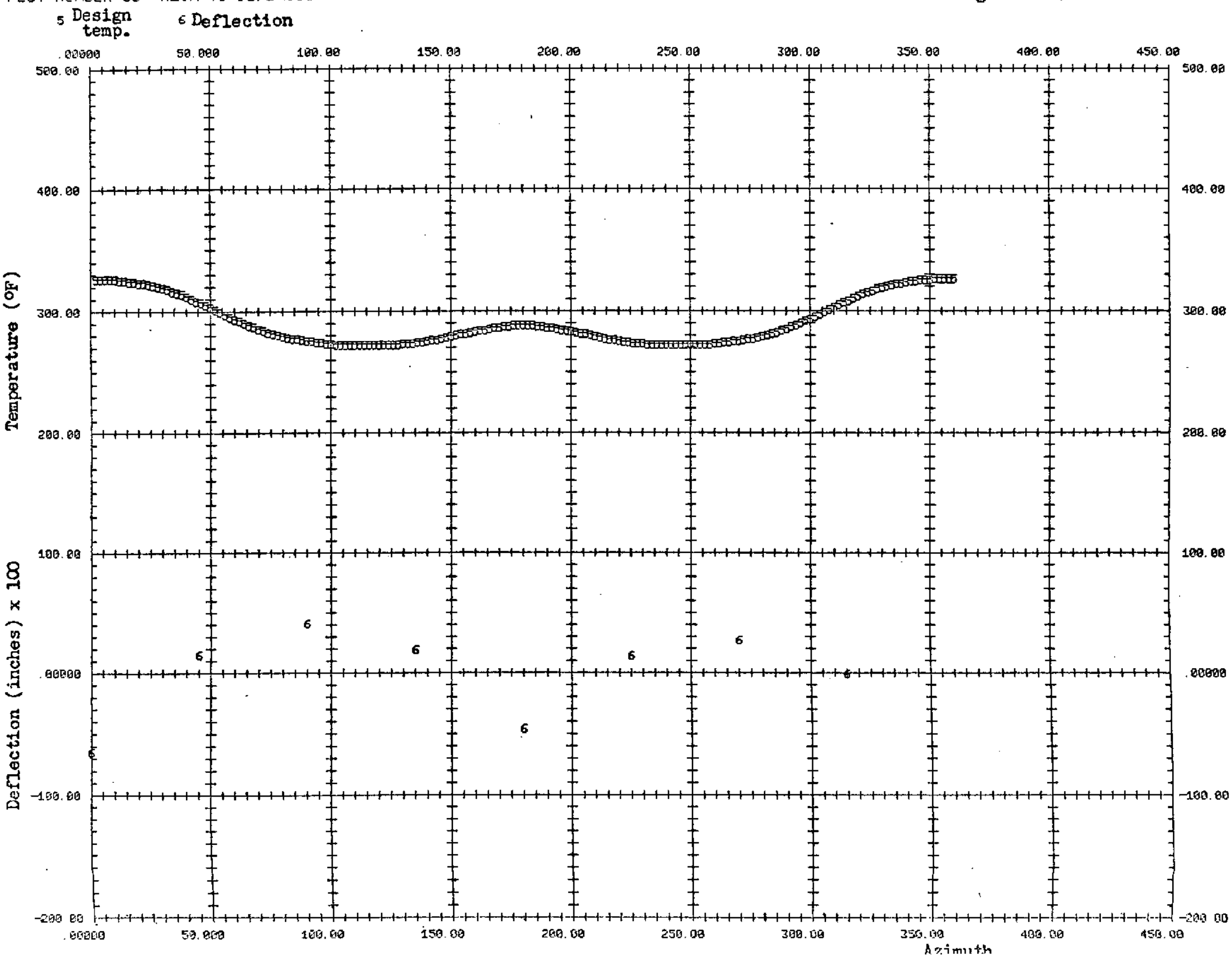


Figure 11.8

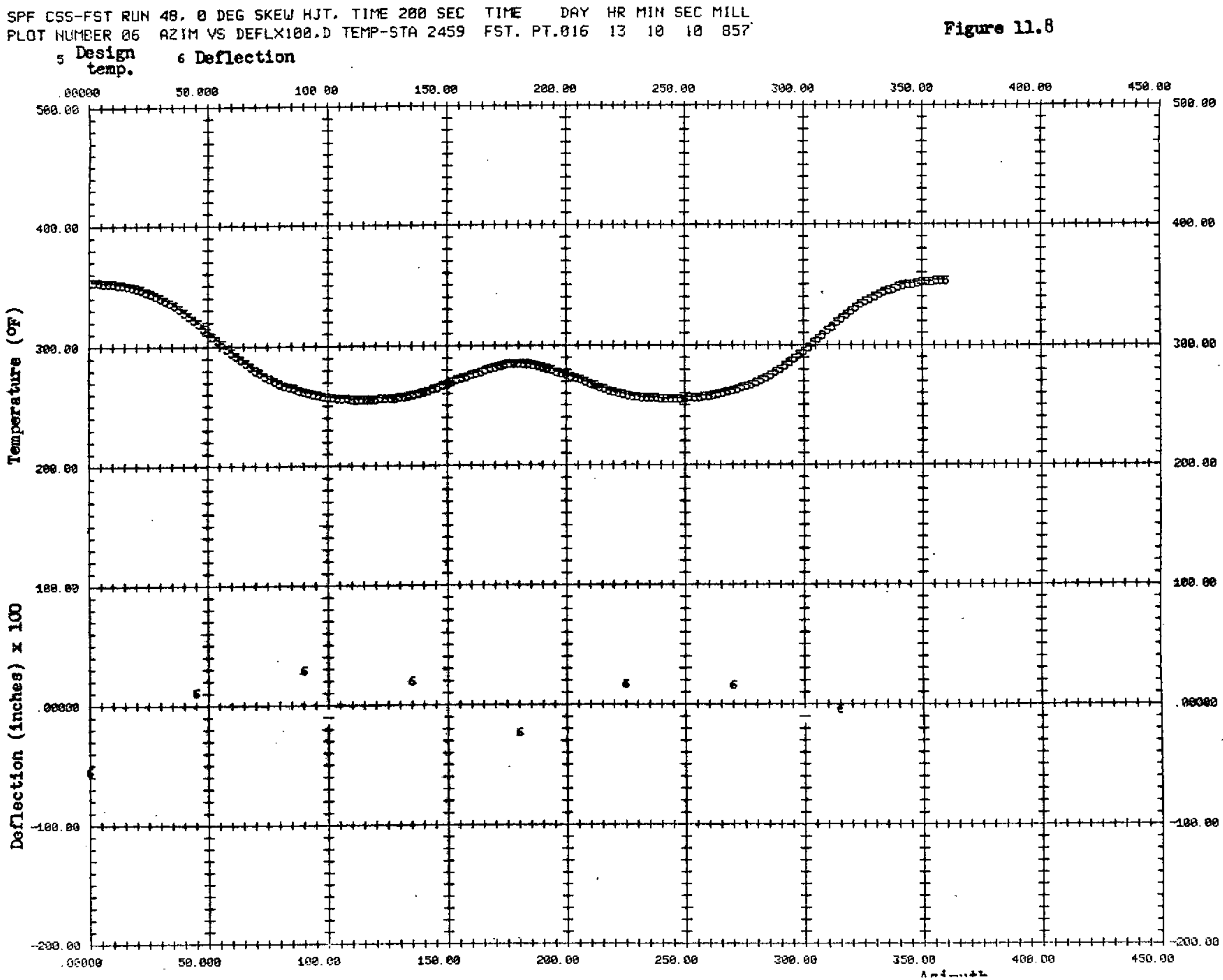
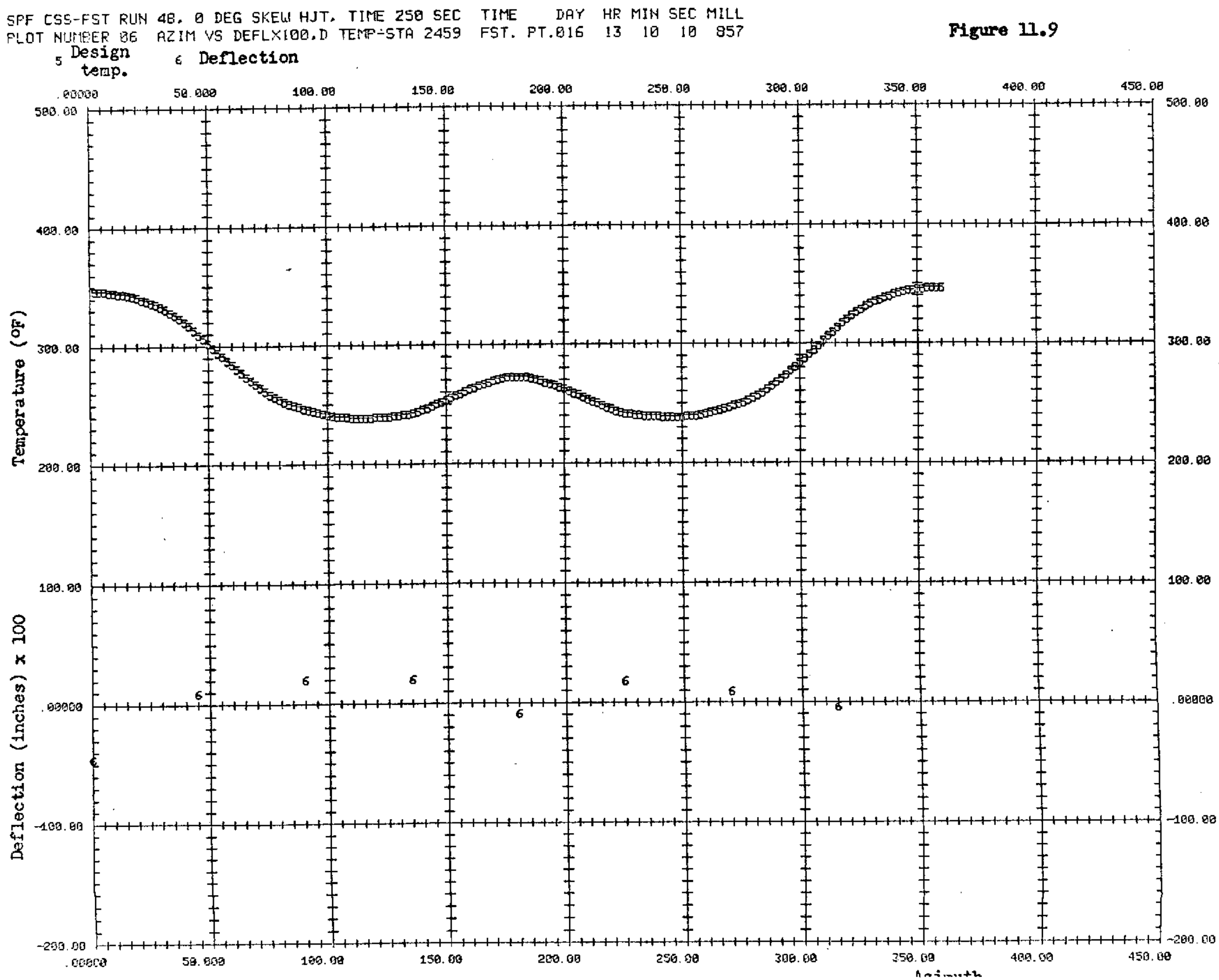
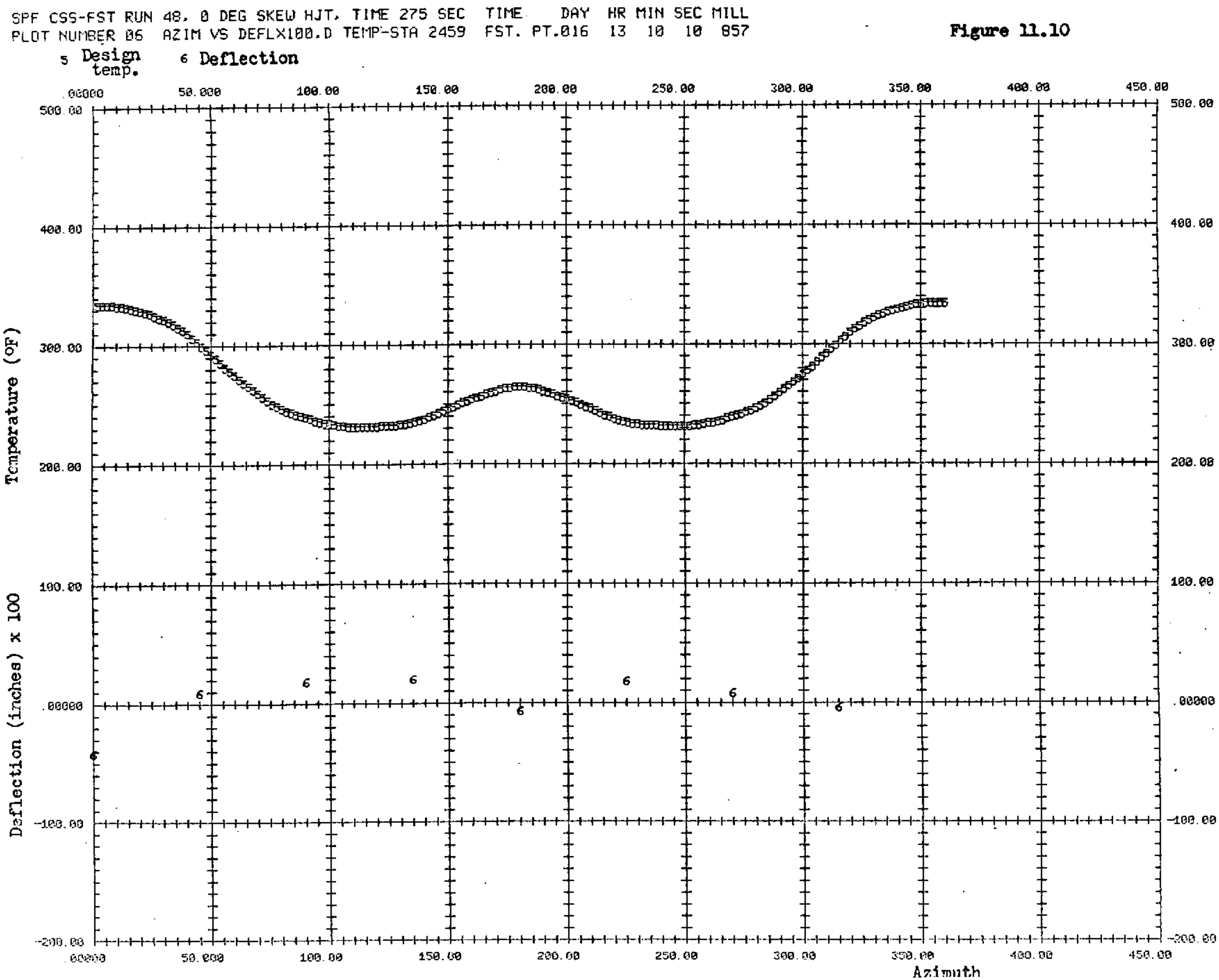

SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 200 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 AZIM VS DEFLX100.D TEMP-STA 2459 FST. PT.016 13 10 10 857
5 Design temp.
6 Deflection
Temperature (°F)
Deflection (inches) x 100
Azimuth

Figure 11.9



SPF CSS-FST RUN 48. 0 DEG SKEW HJT. TIME 250 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 AZIM VS DEFLX100.D TEMP-STA 2459 FST. PT.016 13 10 10 857
5 Design temp.
6 Deflection
Temperature (°F)
Deflection (inches) x 100
Azimuth

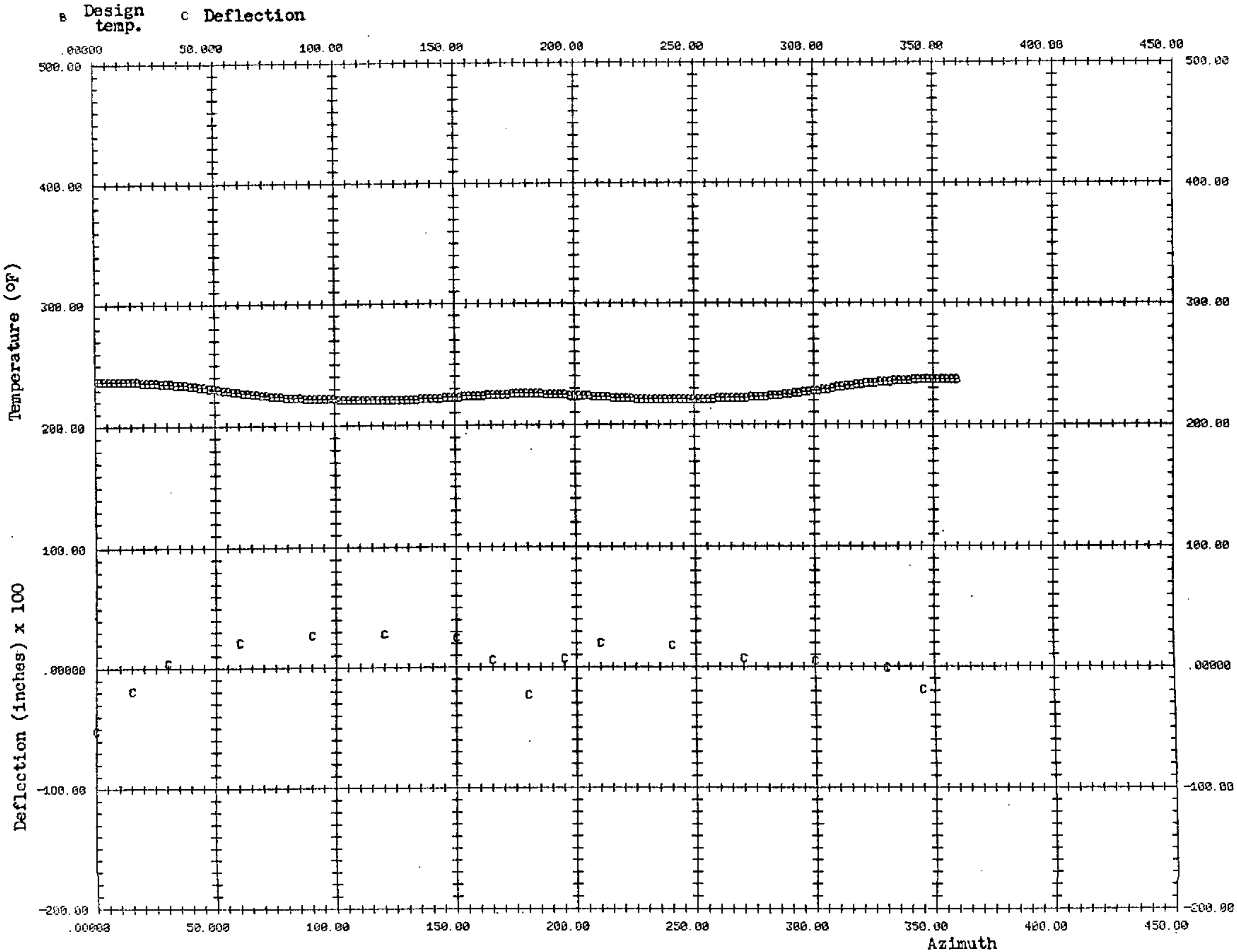
Figure 11.10



SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 275 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 06 AZIM VS DEFLX100.D TEMP-STA 2459 FST. PT.016 13 10 10 857
5 Design temp.
6 Deflection
Temperature (°F)
Deflection (inches) x 100
Azimuth

SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 100 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS DEFLX100.D TEMP-STA 2664 FST. PT.016 13 10 10 857

Figure 11.11



SPF CSS-FST RUN 48. 0 DEG SKEW HJT, TIME 150 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS DEFLX100,D TEMP-STA 2664 FST. PT.016 13 10 10 857

Figure 11.12

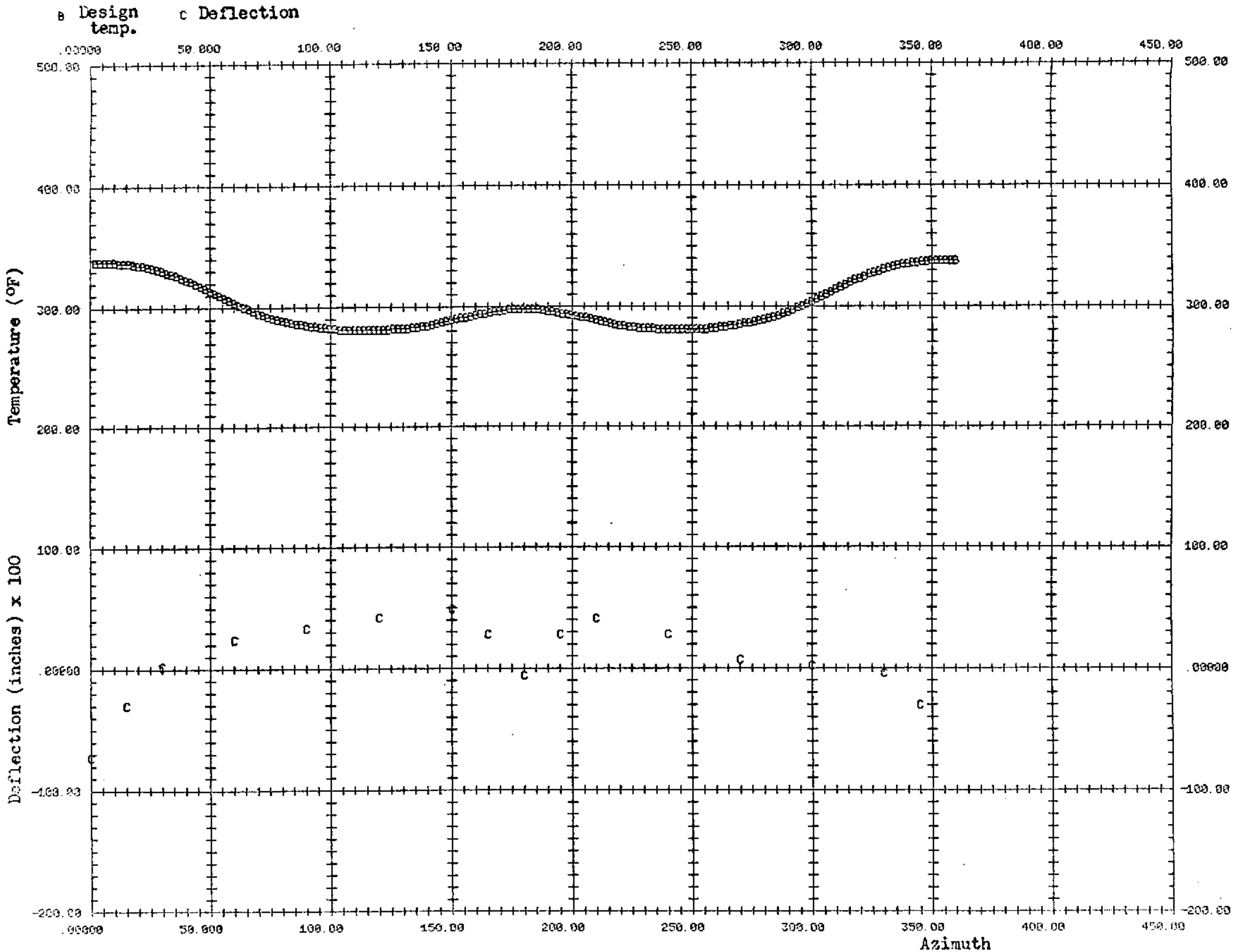
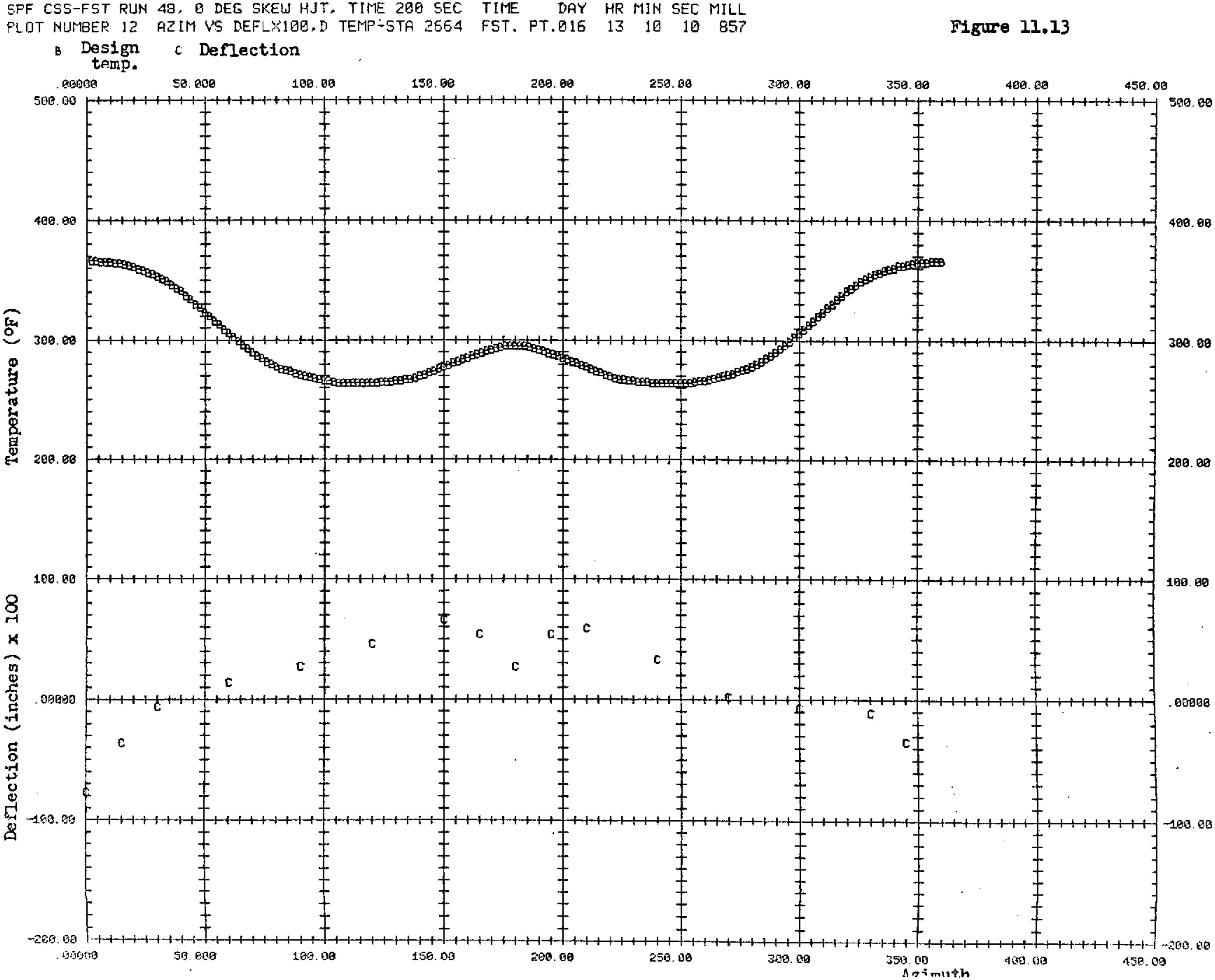


Figure 11.13


SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 200 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS DEFLX100,D TEMP-STA 2664 FST. PT.016 13 10 10 857
B Design temp.
C Deflection
Temperature (°F)
Deflection (inches) x 100
Azimuth
.00000
50.000
100.00
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300.00
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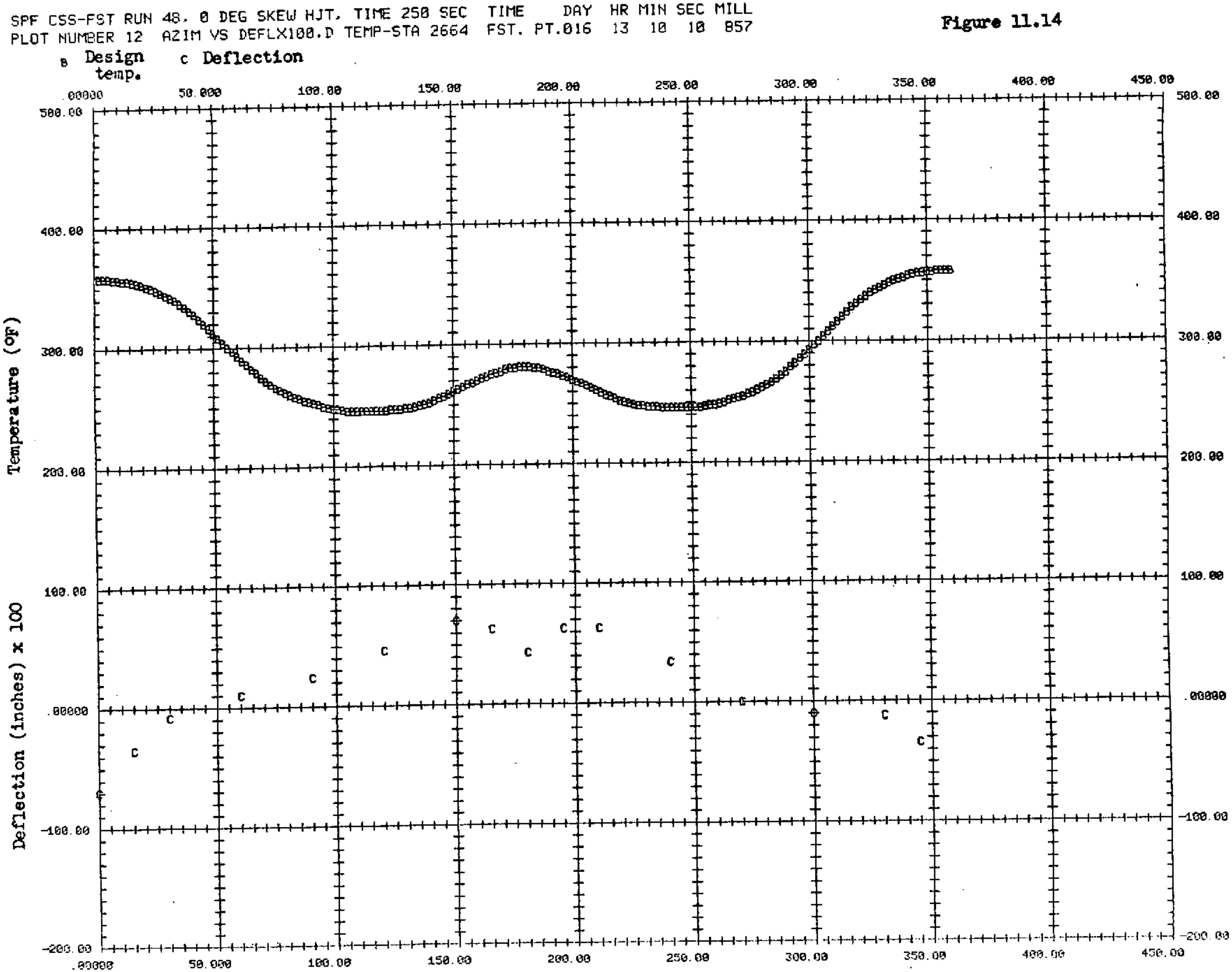
450.00
500.00
-100.00
-200.00

Figure 11.14



SPF CSS-FST RUN 48. 0 DEG SKEW HJT. TIME 250 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS DEFLX100.D TEMP-STA 2664 FST. PT.016 13 10 10 857
B Design temp.
C Deflection
Temperature (°F)
Deflection (inches) x 100
.00000
50.000
100.00
150.00
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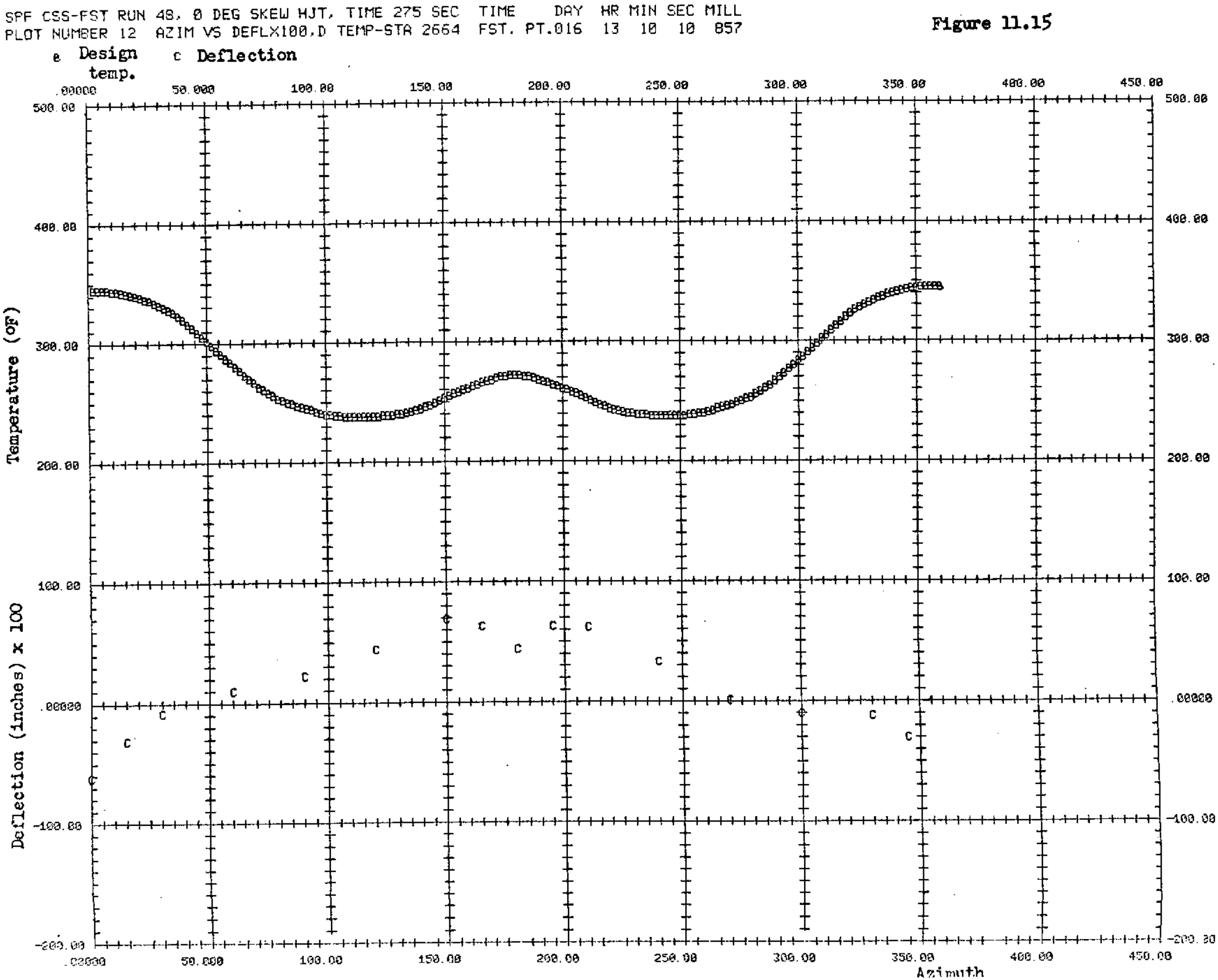
250.00
300.00
350.00
400.00
450.00
500.00
-100.00
-200.00

Figure 11.15


SPF CSS-FST RUN 48, 0 DEG SKEW HJT, TIME 275 SEC TIME DAY HR MIN SEC MILL
PLOT NUMBER 12 AZIM VS DEFLX100,D TEMP-STA 2664 FST. PT.016 13 10 10 857
e Design temp.
c Deflection
Temperature (OF)
Deflection (inches) x 100
Azimuth